The American Midland Naturalist

Devoted to Natural History

Primarily that of the Prairie States

Founded by J. A. Nieuwland, C.S.C.

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Vol. 32, 1944

(July - November)

PUBLISHED BY THE UNIVERSITY OF NOTRE DAME

NOTRE DAME, INDIANA

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Dates of Publication

VOLUME 32, 1944

July	October 27
September	November 18
November	January 26, 1945

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Vol. 32 JULY, 1944 No. 1

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Twenty-five reprints will be given free of charge provided, at least, an equal number is ordered. Authors are requested to submit carefully prepared manuscripts and to limit tables and illustrations as far as possible. Abstracts should accompany manuscripts.

The following numbers are out of print: vol. 1, (1, 3, 5, 8, 11, 12); vol. 2, (1-3, 8-10); vol. 3, all numbers; vol. 4, (1-9, 12); vol. 5, (6-8); vol. 6, (5, 8, 9, 12); vol. 7, (6); vol. 8, (7); vol. 9, (5-7, 9, 10); vol. 10, (8, 9); vol. 11, (1, 5-8, 12); vol. 12, (2, 10-12); vol. 13, (3, 4); vol. 14, (1-5, 7-9); vol. 15, all numbers; vol. 16, all numbers; vol. 17, (1, 2, 4, 5); vol. 18, all numbers; vol. 30, (1). Available issues of vols. 1-14, 30 cents per copy; complete volumes, $3.00 each, except volumes 7, 13, and 14, $1.50 each; vol. 15, $2.00, single issues, 35 cents; vol. 16, $3.00, single issues, 50 cents; vol. 17, $4.50, part 1, $2.00, nos. 2-6, 50 cents each; vol. 18, $3.00; single issues, 50 cents; vols. 19-31, $2.50 each; single issues, $1.00. Subscription price per year, $5.00.

Exchanges for journals, special volumes or duplicate books, and specimens should be arranged directly through the editorial office at the University of Notre Dame, where subscriptions also are received. Offers should accompany request for exchange.

For citation use this abbreviation: *Amer. Midl. Nat.*

The *American Midland Naturalist* is indexed in the INTERNATIONAL INDEX.

Entered as second-class matter at Notre Dame, Indiana. Acceptance for mailing at special rate of postage provided for in section 1103, Act of October 3, 1917, authorized on July 3, 1918.

The American Midland Naturalist

Published Bi-Monthly by The University of Notre Dame, Notre Dame, Indiana

VOL. 32 JULY, 1944 NO. 1

American Cyclopoid Copepods of the viridis-vernalis Group, (Including a Description of Cyclops carolinianus n. sp.)[1]

Harry Clay Yeatman

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[1] A thesis submitted to the Faculty of the University of North Carolina in partial fulfillment of the requirements for the degree of Master of Arts in the Department of Zoology. The work reported on in this paper was done in part while on a fellowship given by the General Education Board.

It is with pleasure that the writer expresses his gratitude to Professor R. E. Coker for constant encouragement and untiring assistance during the course of this investigation, and for the arduous labor of revising the manuscript for publication after the author's induction into military service.

Introduction

Confusion in the identification of North American members of the *viridis-vernalis* group of Cyclops has existed since the earliest taxonomic work on this group. Not only have new species been made from variations of well-known species, as would be expected, but there has been also misidentification attributable, it would appear, to lack of accurate comparisons with the Old World copepods (either with actual specimens or with descriptions and figures by European authorities). Much of the confusion derives from a general failure to recognize that one of our most common copepods is identical with *Cyclops vernalis* Fischer. That species was known to Forbes (1897), but the name soon dropped from American literature, and the species came to be generally but inappropriately called *Cyclops viridis*. Some mistakes have been corrected, but extensive clarification is still a desideratum, which this paper attempts to supply.

Cyclops vernalis and some of its close relatives are so variable in structure as to afford excellent material for experimentation. Correct identification is a necessary prerequisite for experimentation, and, conversely, experimentation assists in solving taxonomic problems, if it proves that species were based upon variations that may be accounted for by differences in environmental conditions. Taxonomy and experimentation should work hand in hand.

Through the kindness of Dr. Waldo L. Schmitt of the U. S. National Museum, I was able to examine and study many American specimens of *C. scutifer* Sars (specimens identified as *C. strenuus* Fischer), *C. vicinus* Uljanin, *C. vernalis* Fischer (specimens identified as *C. americanus* Marsh), and *C. magnus* Marsh, as well as European specimens of *C. strenuus* Fischer and *C. viridis* (Jurine).

I am greatly indebted to my adviser Dr. R. E. Coker for suggestions and helpful criticisms. All his European specimens of *C. viridis* (Jurine), *C. vernalis* Fischer, *C. venustus* Norman and Scott, *C. bicuspidatus* Claus, *C. bisetosus* Rehberg, *C. strenuus* Fischer, and *C. vicinus* Uljanin and his American specimens of *C. vernalis* Fischer, *C. magnus* Marsh, *C. gigas latipes* Lowndes, *C. venustoides* Coker, *C. exilis* Coker, *C. bicuspidatus thomasi* S. A. Forbes, *C. crassicaudis brachycercus* Kiefer, *C. nanus* Sars and *C. varicans rubellus* Lilljeborg were loaned for study during the preparation of this paper. His collections of *C. vernalis* and *C. viridis* contain specimens reared under known experimental conditions.

Only preserved material was available except in the cases of *C. vernalis*, which is common about Chapel Hill, N. C., *C. carolianus*, n. sp., *C. bicuspidatus navus*, *C. crassicaudis brachycercus* and *C. varicans rubellus*, which can usually be found in Chapel Hill. Unfortunately specimens of *C. donnaldsoni* Chappuis, *C. jeanneli* Chappuis, *C. capillatus* Sars, *C. bicolor* Sars, *C. insignis* Claus, *C. nearcticus* Kiefer, *C. dimorphus* Kiefer, copepods identified as *C. ingens* Herrick, and European specimens of *C. gigas* Claus could not be secured; descriptions available in the literature were the sole source of information concerning them.

The copepods under consideration are all members of the Genus *Cyclops* in the narrow definition of Kiefer (1929). The genus is distinguished by the following characteristics:[2]

Anterior part of body oval when viewed dorsally, tapering more posteriorly than anteriorly; last thoracic segment more or less laterally produced; abdominal segments tapering towards the posterior end; furcal rami of various degrees of slimness, but never with outer sides serrated; 1st antennae of 9-18 segments rarely extending beyond the first segment of the body; both branches of swimming feet (P_{1-4}) usually 3-segmented, but, in some species, some or all rami may be 2-segmented by failure of the two distal segments to separate; fifth foot usually 2-segmented, but in some species may be of only one segment, the basal not separated from the last thoracic segment but usually with an outer seta; distal segment of fifth foot small and armed with an apical seta and usually a short, inner, lateral or subapical spine; seminal receptacle simple in structure and the anterior portion generally transversely oval in form.

Following Kiefer's (1929) classification, the subgenera and their characteristics are as follows:—

(a) Subgenus *Cyclops* Kiefer

Furcal rami usually long and slender with inner margins hairy and dorsal surface of each usually with a longitudinal ridge; 1st antennae of 14 or 17 segments, the three distal segments with a line of fine hyaline spines; P_{1-4} with rami of 3 segments, each terminal segment of exopods with 5 setae in addition to spines; P_5 with 2 segments, the basal segment moderately broad with 1 seta at the outer side, the end segment not especially slender, the apex with 1 seta and the middle of the inner side with one strong spine that usually does not exceed the entire length of the end segment (see Fig. 141).

Type: *C.* (*C.*) *strenuus* Fischer

(b) Subgenus *Megacyclops* Kiefer

Furcal rami with inner margins hairy and dorsal surface without longitudinal ridge; 1st antennae short, of 17 segments, and distal segments without line of fine spines; P_{1-4} with rami of 3 segments, each terminal segment of exopod with 4 setae in addition to spines: P_5 with 2 segments, basal segment very broad with one seta at outer side, end segment with a seta at apex and a very small inner spine that may or may not be separated from the segment by a joint (see Figs. 15 & 16).

Type: *C.* (*M.*) *viridis* (Jurine)

(c) Subgenus *Acanthocyclops* Kiefer

Furcal rami without a longitudinal ridge on dorsal surface and with inner margins hairy or not; 1st antennae of 11-18 segments and distal segments without line of fine spines; P_{1-4} with rami usually of 3 segments, each ter-

2 Taken from Kiefer (1929) and Sars (1918).

minal segment of exopods with 4 or 5 setae in addition to spines; P_5 with 2 segments, the basal segment rather broad with one seta at outer side, the end segment slender with a seta at apex and a rather strong inner spine attached just distal to the middle of the segment or almost apical (see Fig. 52).

Type: *C.* (*A.*) *vernalis* Fischer

(d) Subgenus *Diacyclops* Kiefer

Furcal rami without a dorsal longitudinal ridge and usually without hairy inner margins; 1st antennae of 10-17 segments and distal segments without line of fine spines; P_{1-4} with both rami of 3 segments, or both rami of 2 segments, or one ramus of 3 segments and the other of 2 segments; each terminal segment of exopods with 4 setae (if ramus is trisegmented) or 5 setae (if ramus is bisegmented) in addition to spines; P_5 with 1 or two segments, basal segment separated or not from the last thoracic segment, but always with a seta at the outer side; end segment with a seta at the apex and an inner, subapical, long, slender spine (see Figs. 102 & 124).

Type: *C.* (*D.*) *bicuspidatus* Claus

(e) Subgenus *Microcyclops* Claus

Furcal rami with inner margins not hairy and dorsal surface of each without a longitudinal ridge; 1st antennae with 10-12 segments and distal segments without line of fine spines, P_{1-4} with rami of 2 segments, rarely 3; P_5 with one distinct segment, the proximal portion (basal segment of most species) not separated from last thoracic segment but with outer seta usually present; the one free or partly free segment of this foot usually slender with seta at apex and with or without a spine on the inner side (see Figs. 127, 133, 134).

Type: *C.* (*M.*) *varicans* Sars

(f) Subgenus *Metacyclops* Kiefer

Type: *C. (M.) gracilis* Lilljeborg

Kiefer's characteristics of this subgenus do not satisfactorily separate it from Subgenus *Microcyclops* Claus (see p. 73).

Gurney (1933) combines members of the Subgenera *Megacyclops* Kiefer, *Acanthocyclops* Kiefer, and *Diacyclops* Kiefer in the Subgenus *Acanthocyclops*, believing that the differences between the species included are not great enough to warrant placing them in separate subgenera. He also places members of the Subgenus *Metacyclops* Kiefer in the Subgenus *Microcyclops* Claus, but agrees with Kiefer on the Subgenus *Cyclops* Kiefer. Gurney (1933) does not restrict the Genus *Cyclops* Müller as does Kiefer (1929), but ranks several of Kiefer's genera (*Macrocyclops, Ectocyclops, Paracyclops, Eucyclops, Mesocyclops,* and *Cyclops*) as subgenera of the Genus *Cyclops* Müller.

It seems to be mainly a matter of personal opinion whether one considers such species as *C. vernalis* Fischer and *C. viridis* (Jurine) sufficiently distinct to be placed in separate subgenera, or again, whether one restricts the Genus *Cyclops* Müller to as few species as does Kiefer (1929). As shown above, we

prefer to follow Kiefer's 1929 classification except in the case of Subgenus *Metacyclops* whose members we include under Subgenus *Microcyclops*.

The species considered in this study are classified under their subgenera as follows:—

Subgenus *Megacyclops* Kiefer

C. Viridis (Jurine)
C. magnus Marsh
C. gigas Claus
C. gigas latipes Lowndes
C. donnaldsoni Chappuis

Subgenus *Acanthocyclops* Kiefer

C. vernalis Fischer
C. carolinianus, n. sp.
C. exilis Coker
C. venustoides Coker
C. venustus Norman and Scott
C. capillatus Sars

Subgenus *Diacyclops* Kiefer

C. bicuspidatus Claus
C. bicuspidatus thomasi S. A. Forbes
C. bicuspidatus navus Herrick
C. bisetosus Rehberg
C. nearcticus Kiefer
C. jeanneli Chappuis
C. crassicaudis Sars
C. crassicaudis brachycercus Kiefer
C. nanus Sars

Subgenus *Microcyclops* Claus

C. varicans Sars
C. varicans rubellus Lilljeborg
C. bicolor Sars
C. dimorphus Kiefer

Subgenus *Cyclops* Kiefer

C. strenuus Fischer
C. scutifer Sars
C. vicinus Uljanin
C. insignis Claus

Explanation of Terms Used

All the descriptions refer to the female copepod unless otherwise stated.

Length of body of copepod refers to the measurement of a median straight line from the anterior tip of the first segment of the body (cephalothorax) to the middle of a line between the apices of the furcal rami (antennae and furcal setae not included). Live specimens are better to measure than dead ones, as the former are much less likely to have their body segments telescoped over one another or unnaturally extended—conditions which require the measurement of individual body segments to get the total length.

Length of spines and setae refers to the measurement of a line from middle of base to the apex of such structures.

Length of furcal ramus refers to the measurement in a straight line from base of ramus to base of longest terminal seta and parallel to the inner margin of the ramus (see Fig. 2).

Width of furcal ramus refers to the measurement in a straight line from inner to outer side exactly bisecting and forming a right angle with the length line (see Fig. 2).

FW/FL refers to the quotient of furcal length into furcal width.

P_{1-4} refers to the 4 pairs of swimming feet.

P_5 refers to the small fifth pair of feet.

Spine formula refers to the numbers of spines on the terminal segments of exopods of the first through the fourth pairs of swimming feet. For example, a copepod with spine formula of 2, 3, 3, 3, has 2 spines on the terminal segment of exopod P_1, 3 spines on the terminal segment of exopod P_2, and so on.

Endopod 3 of P_4 refers to the terminal segment of endopod of the fourth swimming foot.

Length of endopod 3 of P_4 refers to the measurement of a straight line from base of the segment to the base of the inner terminal spine and parallel, as nearly as possible, to the outer side of the basal portion (see Fig. 5).

Width of endopod 3 of P_4 refers to the measurement of a straight line from one side to the other, half the distance from base of outer seta to base of proximal inner seta and forming a right angle with the length line (see Fig. 5).

Systematic Treatment

KEY TO THE GENUS CYCLOPS MÜLLER AS NARROWLY DEFINED BY KIEFER, 1929; OR THE VIRIDIS-VERNALIS GROUP IN THE BROAD GENUS CYCLOPS AS GENERALLY RECOGNIZED. (FOR SPECIES FOUND IN NORTH AMERICA AND SEVERAL NOT YET FOUND IN N. A., BUT TO BE EXPECTED.)

1 (8) Three distal segments of 1st antenna with row of fine hyaline spines (Figs. 138 and 156); furcal rami usually with longitudinal dorsal ridge (Fig. 137); second segment of P_5 with apical seta and a large spine attached at middle of inner side of segment (Fig. 141). Subgenus CYCLOPS..... 2

2 (3) 1st antenna of 14 segments ..... *C. insignis*

3 (2) 1st antenna of 16 or 17 segments 4

4 (5) Spine formula of terminal segments of exopods of P_{1-4}: 2, 3, 3, 3..*C. vicinus*

5 (4) Spine formula: 3, 4, 3, 3 6

6 (7) 4th and 5th thoracic segments laterally expanded into pointed wings; furcal rami usually 4 times as long as broad; innermost terminal furcal seta much longer than ramus ..... *C. scutifer*

7 (6) 4th and 5th thoracic segments not laterally expanded, but usually with small projections at postero-lateral angles of these segments; furcal rami usually at least 5 to 7 times as long as broad; innermost terminal furcal seta usually shorter than ramus ..... *C. strenuus*

8 (1) Distal segments of 1st antenna without hyaline spines; furcal ramus without dorsal ridge; 2nd segment of P_5 with apical seta and small or slender spine on the inner side, usually near apex (Figs. 15, 16, 52 and 102) 9

9 (48) P_5 with 2 segments 10

10 (31) P_5 with apical seta and small spine or spur midway of inner margin or somewhat longer subapical spine 11

11 (20) 2nd segment of P_5 with apical seta and small spine or spur about midway of inner side (Figs. 15 and 16); furcal rami with inner margins hairy; 1st antenna of 17 segments. Subgenus MEGACYCLOPS 12

12 (13) Inner terminal spine of endopod of P_4 always shorter than outer terminal spine ..... *C. magnus*

13 (12) Inner terminal spine of endopod of P_4 always longer than outer terminal spine 14

14 (17) Setae of terminal segment of endopod of P_4 not extending to distal end of inner terminal spine 15

15 (16) Innermost terminal furcal seta much longer than ramus ..... *C. viridis*

16 (15) Innermost terminal furcal seta shorter or not much longer than furcal ramus ..... *C. gigas*

17 (14) Setae of terminal segment of endopod of P_4 extending beyond distal end of terminal spine 18

18 (19) Innermost terminal furcal seta not quite twice as long as outermost ..... *C. gigas latipes*

19 (18) Innermost terminal furcal seta about 3 times as long as outermost ..... *C. donnaldsoni*

20 (11) 2nd segment of P_5 with apical seta and inner spine just distal to the middle of the segment or almost apical (Figs. 52 and 87); furcal rami with or without hairs on inner margins. Subgenus ACANTHOCYCLOPS 21

21 (24) 1st antenna of 17 segments (occasionally 18) 22

22 (23) Inner margins of furcal rami without hairs ..... *C. vernalis*

23 (22) Inner margins of furcal rami with tufts of fine hairs ..... *C. carolinianus*

24 (21) 1st antenna with less than 17 segments 25

25 (30) 1st antenna of 12 segments 26

26 (29) Inner margins of furcal rami with small hairs 27

27 (28) Setal formula of terminal segments of exopods of P_{1-4} 5, 5, 5, 5; posterolateral angles of next to last thoracic segment produced (as in *vernalis*) ..... *C. venustus*

28 (27) Setal formula of terminal segments of exopods of P_{1-4} 4, 4, 4, 4; posterolateral angles of next to last thoracic segment not produced ..... *C. venustoides*

29 (26) Inner margins of furcal rami without hairs ..... *C. capillatus*

30 (25) 1st antenna of 11 segments ..... *C. exilis*

31 (10) 2nd segment of P_5 with apical seta and inner subapical, long slender spine (figs. 102, 124); furcal rami without hairs. Subgenus DIACYCLOPS 32

32 (43) 1st antenna of 17 segments 33

33 (36) Outer lateral furcal seta attached at a point 3/4 to 4/5 of the distance from base to apex of ramus (see also *bicuspidatus navus* below); innermost terminal furcal seta shorter or barely longer than outermost 34

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44 (45) 1st antenna of 14 segments ..... *C. bicuspidatus lubbocki*

45 (44) 1st antenna of less than 14 segments 46

46 (47) 1st antenna with 12 segments..... *C. crassicaudis brachycercus*

47 (46) 1st antenna of 11 segments ..... *C. nanus*

48 (9) P_5 of 1 segment, the usual basal segment not being separated from the 5th thoracic segment; the distinct or partly distinct segment of P_5 with an apical seta and with or without an inner spine (Figs. 127 and 133); P_{1-4} with rami of 2 segments. Subgenus MICROCYCLOPS (including Kiefer's subgenus *Metacyclops*) 49

49 (50) Free segment of P_5 broader than long and with a strong spine on the inner side 51

50 (49) Free segment of P_5 longer than broad and with or without a tiny spine on the inner side 51

51 (52) Inner of the 2 middle furcal terminal setae noticeably longer than outer median and at least as long as all of the abdominal segments and the furcal ramus combined. 1st antenna of 11 or, usually, 12 segments..... ..... *C. varicans, C. v. rubellus*

52 (51) Inner of the 2 middle terminal furcal setae only slightly longer than outer median and much shorter than abdominal segments and furcal ramus combined; 1st antenna of 10 or, usually, 11 segments..... *C. bicolor*

CONFUSION OF C. VIRIDIS AND C. VERNALIS

As previously mentioned, many American students of copepods have linked the various forms of *C. vernalis* Fischer with *C. viridis* (Jurine) although the two species involved are so distinct as to be assigned by Kiefer (1929) to different subgenera. Apparently *viridis* occurs in this country, but is rarely found; I have not seen American specimens. *Vernalis*, on the other hand, occurs almost everywhere and is probably the most variable in form of any American copepod. None of its forms need, however, be confused with *viridis*. The name of *C. insectus* S. A. Forbes (1882), *C. parcus* Herrick (1882), *C. uniangulatus* Cragin (1883), *C. brevispinosus* Herrick (1884), and *C. americanus* Marsh (1893) have been proposed for the variants of *vernalis*. Marsh in 1893 considered *C. brevispinosus* Herrick, *C. parcus* Her-

rick, and *C. americanus* Marsh as distinct species, with the suggestion that *C. brevispinosus* and *C. americanus* were possibly the same, the former being a limnetic variant. He thought them closely related to *C. viridis* (Jurine). *C. parcus*, he said, had armature of P_{1-4} like that of *C. pulchella* Sars (Type A, see Table 2) and P_5 like that of *C. americanus* and *C. brevispinosus*.

Herrick in 1895 considered *C. vernalis* Fischer, *C. robustus* Sars, *C. brevispinosus* Herrick, *C. parcus* Herrick, and *C. uniangulatus* Cragin as separate species and unfortunately placed *C. americanus* Marsh as a subspecies of *C. viridis* (Jurine). His descriptions of *C. vernalis* Fischer and *C. robustus* Sars were taken from Schmeil and he made no reference to their occurrence in America. He mentioned that the terminal spines of the P_4 endopod of *C. americanus* had relative lengths the reverse of those shown in Marsh's figure; we know now, however, that either terminal spine may be the longer. Herrick regarded *C. parcus* as very near to *C. vernalis* and *C. viridis* and like *C. pulchellus* Sars (now *C. bicuspidatus* Claus) in swimming feet; (for armature of *C. pulchellus* and *C. parcus* of Type A, see Table 1). The seminal receptacle of *C. parcus* (now *C. vernalis*) was described and figured as transversely oval and very similar to that of *C. vernalis*.[3] Although ranking *C. brevispinosus* as a distinct species, Herrick spoke of it as the pelagic [limnetic] representative of *C. parcus*, with more slender body, furcal rami more elongated, both outer caudal setae represented by spines, and P_4 of distinct form. He thought *C. uniangulatus* Cragin was like *C. parcus*, although it had been described as having three inner setae instead of two on the terminal segment of the outer ramus of P_1; Cragin may have made a mistake or the specimen may have been abnormal.

E. B. Forbes (1897) considered *brevispinosus* Herrick and *insectus* S. A. Forbes as subspecies of *C. viridis* (Jurine); *uniangulatus* Cragin, *parcus* Herrick, and *americanus* Marsh were given as synonymous of *insectus* S. A. Forbes (which he did not relate to *vernalis*). *Brevispinosus*, he said, differed from the European *C. viridis* in: (a) outer terminal seta of furcal ramus (a spine instead of a seta in *brevispinosus*, but he said that there were intermediates between a spine and a seta in some examples), (b) size of the inner spine of second segment of P_5 (larger in *brevispinosus*), (c) armature of P_{1-4} (Type A in *viridis* and Type C in *brevispinosus*, see Table 1), and (d) bareness of inner margins of furcal rami (hairy in *C. viridis* and not in *brevispinosus*). *C. viridis insectus* was described as differing from *C. viridis* in (b) and (d) of above and as having a slight difference in shape of the seminal receptacle and a very variable armature of P_{1-4}. Forbes was correct in considering *C. insectus (C. americanus, C. uniangulatus, C. parvus)* and *C. brevispinosus* as being the same species, but wrongly linked them with *C. viridis* instead of *C. vernalis*. Forbes did, however, mention *C. vernalis* as occurring in small numbers in Lake Geneva, Wis.; he had examined European specimens sent by Sars.

Lehmann (1903), under the direction of Marsh, attempted to find definite

[3] Marsh, Forbes and Chambers failed to note the resemblance of *C. parcus* to *C. vernalis*.

structural differences between copepods identified as *brevispinosus* and *americanus* by Marsh. Using 35 specimens of the former, collected from large bodies of water in the Great Lakes region, and 11 specimens of the latter, from pools of widely different parts of the United States, she compared the two forms as to length of furcal ramus, width of furcal ramus, form and length of the outermost apical seta or spine of the furcal ramus, and armature of the outer side of endopod 3 of P_4. In the proportions of the furcal rami there was considerable overlapping. The outermost terminal spine of the furcal ramus of *brevispinosus* varied "from a very blunt spine to a slender, seta-like spine, the greatest number being thick at the base but tapering rapidly toward the apex." No very slender seta, such as is occasionally found on *americanus,* was found on the outer side of the furcal ramus of *brevispinosus* and no thick blunt spine, such as is occasionally found in *brevispinosus,* was found at this point on *americanus*. The "slender, tapering spine" (which she figures as being hairy and which I would call a short seta) was found most frequently in both forms. All the specimens of *brevispinosus* had a spine instead of a seta on the outer endopod 3 of P_4, while the *americanus* specimens frequently bore a seta at this point. Some individuals identified as *americanus* had a spine on the outer side of this segment and, in some instances, Lehmann was not sure of the identity of the specimens. Since the structure of *brevispinosus* (which came from large bodies of water that are not subject to sudden or marked changes) was more uniform than that of the variable *americanus* (which came from small, weedy pools that often dry up and are easily polluted), it was thought that environment might have some influence on variability. Lehmann concluded that the characters she dealt with were unreliable for specific distinction between *brevispinosus* and *americanus,* and that her results were not conclusive because of insufficient numbers of specimens. Unfortunately she did not attempt any breeding experiments.

Byrnes (1909) stated that *C. americanus, C. parcus,* and *C. brevispinosus* were of the *viridis* type, but did not consider them subspecies or varieties of *C. viridis* (Jurine). Concerning the similarity of *parcus* and *americanus,* she stated: "the close agreement between *C. parcus* and *C. americanus* in their resemblance to the form Dr. Forbes described as *C. insectus* is, it seems to me, explained by the probability that they are heterogeneous forms of the same species." The spine formula of the terminal segments of the exopods of P_{1-4} of *parcus* was given as 2, 3, 3, 3 and of *americanus* as 3, 4, 4, 4;[4] she noted, however, that *brevispinosus* could have either spine formula and that the spine formula of *americanus* sometimes varied, so did not consider this difference very important. Sometimes she found both *americanus* and *parcus* together in the same pools, which might indicate that they grew up under similar environmental conditions, but I think the *parcus* form probably developed when the temperature was high, its life span overlapping that of *americanus* which probably developed at lower temperatures. *Brevispinosus* was described as resembling *americanus* and *parcus* in its larger outlines and in its form of seminal receptacle, but it had shorter furcal rami, a spine instead of a

4 Byrnes did not use the term "spine formula," but, to shorten her descriptions, we give the armatures of the swimming feet of her copepods in terms of spine formulas.

seta on the outer border of endopod 3 of P_4 (sometimes 2 spines instead of a spine and a seta at the apical end of endopod of P_3 and even other seta of P_{1-4} replaced by spines), and usually a relatively broader P_5. In February and March, *brevispinosus* individuals which Byrnes took from an aquarium had a 3, 4, 4, 4 spine formula, but those taken from the same aquarium 9 months later had a 2, 3, 3, 3 spine formula. The characteristic spine on the outer margin of endopod 3 of P_4 was invariably present. She then reared specimens (all males) with a 3, 4, 4, 4, spine formula from females with a 2, 3, 3, 3 spine formula. No offspring with a 2, 3, 3, 3 spine formula could be reared from females with a 3, 4, 4, 4 formula, possibly because the cultures were not kept at suitable temperatures (see p. 37). Byrnes was one of the first American authors to note that the spine formula of *brevispinosus* offspring is not necessarily like that of their female parents. Unfortunately, she did not perform careful breeding experiments under known and constant conditions of environment. Although she did not confuse *americanus, parcus,* and *brevispinosus* with *C. viridis* (Jurine), she failed to compare them with *C. vernalis* Fischer.

Marsh (1910) influenced by Forbes' paper of 1897, correctly recognized that *C. brevispinosus, C. parcus,* and *C. americanus* (*C. insectus*) were all of one species, but, without evident reason, ranked them as subspecies of *C. viridis.*

Chambers (1912) considered *C. americanus, C. parcus* and *C. brevispinosus* as separate species and distinct from *C. viridis.* He compared *C. americanus* and *C. parcus* with *C. viridis,* and found the following differences: *C. viridis* has the inner margin of furcal ramus hairy, while the furcal ramus of *C. parcus* and *C. americanus* is not hairy. The spine formula of exopod of P_{1-4} in *C. viridis* and *C. parcus* is 2, 3, 3, 3; while in *C. americanus* it is 3, 4, 4, 4. The average lengths are *C. viridis* 2.2 mm. (Wolf), *C. parcus*—1.4 mm. and *C. americanus*—1.5 mm. The chromosome number is given for *C. viridis* as 12 (Haecker 1897, Braun 1909); *C. parcus,* 6; *C. americanus,* 10. Chambers' figures show that P_5 in *C. viridis* has a small inner spine at about the middle of segment 2, while the P_5 in *C. americanus* and *C. parcus* has a larger spine closer to the distal end of segment two. The seminal receptacle is drawn with a concave anterior border in *C. viridis* and *C. parcus* and with a convex anterior border in *C. americanus.* Chambers was correct in separating *C. parcus* and *C. americanus* from *C. viridis,* but unfortunately did not make comparisons with *C. vernalis. C. vernalis* can have either the spine formula of *parcus* or that of *americanus,* as well as the body lengths and forms of seminal receptacles of these forms. Eggs of *C. vernalis* taken from one batch may yield copepods of both *parcus* and *americanus* types (Coker 1934). The difference in chromosome number between *parcus* and *C. vernalis* is the only obstacle in considering *C. parcus, C. vernalis,* and *C. americanus* as the same species. Braun (1909) found that *C. vernalis* had 10 chromosomes which is the number characteristic of *americanus,* while Chambers found only 6 in *C. parcus.* He had specimens from Toronto, Woods Hole, and New York, and found the chromosome number to be constant both for *C. parcus* and *C. americanus.* Chamber's record of chromosome number for *parcus* raises a question which

is now unanswerable. Certainly the somatic characters he describes and figures will not distinguish these copepods from those reared from eggs of *vernalis*. Coker (1934) suggests that Chambers might have been "dealing with representatives of an undescribed species, intermediate between *vernalis* and *viridis*." Gurney (1933) is of the opinion that Chambers should have given descriptions of the furcal rami and fourth swimming feet of these copepods.

Later in the year (1912a), Chambers published another paper on the chromosomes of *parcus, americanus,* and *brevispinosus*. In this paper he briefly reviewed the somatic and chromosome number differences between *parcus* and *americanus,* brought out in his previous paper, and described *brevispinosus,* which is larger than either *parcus* or *americanus,* the body length of the female being 1.6 mm. It may have the spine formula of the terminal segments of the exopods of P_{1-4} either like that of *parcus* (2, 3, 3, 3) or like that of *americanus* (3, 4, 4, 4) but it always differs from these forms by having a spine instead of a seta on the outer margin of endopod 3 of P_4, slightly thicker and shorter "caudal styles" (presumably he means the terminal furcal setae although these words have been used by some writers to mean the furcal rami), and a diploid chromosome number of 4 instead of 6 (*parcus*) or 10 (*americanus*). These four chromosomes are said to be far larger than those of either *parcus* or *americanus*. Although Chambers' figures of the chromosomes of these copepods are very good, they would be more convincing had he described his specimens thoroughly. Since I have repeatedly reared from a single female of *C. vernalis* offspring externally inseparable from *americanus, parcus,* and *brevispinosus,* I do not recognize these forms as distinct species.

In 1920, Marsh, influenced by Chambers, reverted to his 1893 classification, making *C. brevispinosus, C. americanus,* and *C. parcus* distinct species. *C. insectus,* S. A. Forbes, although an older name than *C. americanus* Marsh, was placed in the synonymy of the latter, since "the original description of *C. insectus* was in such form that the species could not be recognized."[5] Marsh, to whom students of American copepods owe so much, seems never to have mentioned *C. vernalis* in his writings and Chambers also failed to do so. Without consideration of that species, confusion was inevitable.

The work on *C. vernalis* by the European authors is well summarized by Gurney (1933) and Coker (1934) so that it need not be discussed here. In their papers, *C. elongatus, C. lucidulus, C. robustus, C. parcus, C. brevispinosus, C. americanus,* etc., are properly made synonyms of *C. vernalis*.

With respect to the leading European authors, Sars (1918) recognized the distinction between *americanus* and *viridis* (called *C. vulgaris*), placed *brevispinosus* in the synonymy of *robustus* Sars, and identified the specimens of *parcus* supplied him by Prof. Forbes as *C. lucidulus (vernalis);* Kiefer (1929) placed *parcus* in the synonymy of *vernalis* and both *americanus* and *brevispinosus* in that of *robustus* (subsequently identified by Gurney (1933) and Coker (1934) as a variant of *vernalis*); Gurney (1933) placed *robustus,*

[5] We agree with Marsh in making the scantily described *insectus* a synonym of *vernalis americanus*.

brevispinosus, insectus, parcus, and *americanus* in the synonymy of *C. vernalis.* Here we are not concerned with the general nomenclatural history of *vernalis* and *viridis.* Those who may be interested are referred to the standard works of Schmeil (1892), G. O. Sars (1918), Kiefer (1929), and Gurney (1933).

DIFFERENCES BETWEEN C. VIRIDIS AND C. VERNALIS

The confusion of *C. vernalis* and its variants with *C. viridis,* so deeply rooted in the American literature, necessitates a careful comparison of the two species complexes.

1. Body length exclusive of the furcal setae for the *C. vernalis* female, according to several authors, rarely approaches 2 mm. and is usually much less: 1.2 to 1.7 mm., Schmeil (1892), Pesta (1928), and Kiefer (1929); 1.3 to 2.0 mm., Wolf (1905); 1.40 to 1.50 mm. (for *C. lucidulus*) and 1.20 mm. (for *C. robustus*), Sars (1918); 0.84 to 1.78 mm., Coker (1934); and 1.0 to 1.8 mm., Gurney (1933). My specimens vary from 0.9975 mm. to 1.83 mm.

C. viridis, on the other hand, frequently has a length of 2 mm. or much more: 1.90 mm., Lilljeborg (1901) and Sars (1918); 1.5 to 2.5 mm., Kiefer (1929); 1.5 to 3.0 mm., Gurney (1933); and 1.61 to 2.33 mm. in my collections. Length given for *C. viridis,* by the authors who consider *C. gigas* a variety of *C. viridis,* would naturally be greater, but are not included here. There is some overlapping in the lengths of the two species, but *C. viridis* averages considerably larger than *C. vernalis.* The difference in appearance is generally greater than is indicated by the measurement of length alone. *C. viridis* is robust, heavy-bodied and relatively slow in movement (Coker, 1934), while the lighter-bodied *C. vernalis* is a very active species (see Figs. 1 & 47).

2. *C. viridis* lacks outward extensions of the postero-lateral angles of the dorsum of the next to last thoracic segment which are ordinarily prominent in *C. vernalis* (see Figs. 1 & 47).

3. In *C. viridis* the posterior margins of the abdominal segments (except the last, which has its posterior margin armed with small spines) are coarsely serrated; in rare cases, the serrations are inconspicuous. In *C. vernalis,* the posterior margins of the abdominal segments are not, or are but very slightly serrated.

4. The inner margins of the furcal rami are densely covered with minute hairs in *C. viridis,* while the furcal rami of *C. vernalis* are bare. Ectoparasites, which are commonly found on copepods, should not be confused with hairs.

Our new species *C. carolinianus,* which resembles *C. vernalis* very closely, has tufts of small hairs on the inner margins of its furcal rami and might possibly be confused with *C. viridis.* It differs, however from *C. viridis* in practically all the other points mentioned here (see pp. 37-40).

5. Relative lengths of terminal furcal setae differ in two species:—in *C. viridis* (innermost to outermost seta) there are found such ratios as *2.25*: *7.17*: *5.17*: *1* and *2.30*: *7.17*: *5.07*: *1;* in *C. vernalis,* such ratios as from *1.25*:

7: *5.41*: *1* and *1.81*: *8.75*: *5.06*: *1*. The innermost terminal seta is relatively longer in *C. viridis* (longer than the furcal ramus) than in *C. vernalis* (shorter than the furcal ramus) (see Figs. 17 & 48).

6. The first antennae of both species are of 17 segments but variants in which 18 segments are formed by the division of the normal 7th segment, or rarely the 4th, occur occasionally in *C. vernalis* (Coker 1934). Claus (1863) described such a variant as a new species under the name of *C. elongatus*, but Schmeil and others, as a result of collections or of breeding experiments, have placed *C. elongatus* in the synonymy of *C. vernalis*. Such a variation seems not to have been recorded for *C. viridis*, except for a single example reared by Coker (1934), having 18 segments by the division of the 7th. As usual, *C. vernalis* is the more variable species, but no definite distinction can be made by the segmentation of the antennae.

The aesthete at the distal end of the 12th segment (13th segment, if antenna consists of 18 segments) of the first antenna is relatively longer in *C. vernalis* than in *C. viridis*. In *C. vernalis* it reaches to the distal end of segment 14 (segment 15 in the 18-segmented antennae), while in *C. viridis* it reaches only to the middle of segment 14.

7. *C. viridis* has the inner terminal spine of endopod 3 of P_4 always longer than the outer, while in *C. vernalis*, the two spines are about equal, with either the inner or the outer slightly longer.

8. The armature of the swimming feet of the *C. viridis* is of Type A (see Table 1), while in *C. vernalis*, it may be of Type A, of Type B, of Type C, (see Table 1) or any combination of these three Types. Even the larger specimens of *C. viridis* have the lower spine formula 2, 3, 3, 3 of the exopods of P_{1-4}. *C. vernalis*, which seems to have the most variable spine formula of any copepod, usually has the higher formula—3, 4, 4, 4, in the larger examples of the *robustus* type. Usually it is the small *C. vernalis*, without the size range of *C. viridis*, which have a spine formula which could be confused with *C. viridis*.

9. The fifth foot of *C. viridis* differs from that of *C. vernalis* chiefly in the small inner lateral spine of the second segment. In *C. viridis*, this spine is very small, jointed or not, and inserted just distal to the middle of the segment. In *C. vernalis*, this spine is more apical, relatively longer, and seems to be always jointed (see Figs. 16 & 52).

10. According to Haecker (1897), Braun (1909), and Chambers (1912), the European type of *C. viridis* has 12 chromiomes; and according to Braun (1909) *C. vernalis* has 10 chromosomes for the diploid number. Chambers (1912) found 10 chromosomes to be the number in *C. americanus* (which is now recognized to be *C. vernalis*).

A decided difference in rate of development has been reported for the two species. Under favorable conditions, *C. vernalis* completes a life cycle in about one week, while *C. viridis*, bred under like conditions, may take three weeks

or more (Coker 1934). Coker (1934) was not able to effect a cross between *C. viridis* and *C. vernalis*.

Shape of the seminal receptacle has been stressed by many authors as significant in taxonomic work. Its form is important, but varies within certain limits. For *C. viridis*, the anterior margin of the seminal receptacle, according to all available literature and in all specimens which I have observed, is concave, but in the individuals of one line the degree of concavity varies to some extent. Some had conspicuously concave anterior margins, while others had only a slight median indentation (see Figs. 6 & 7). Gurney (1933, Figs. 1563-1564-1582) shows how great is the diversity of shape of the seminal receptacle of *C. viridis*. According to Gurney (1933), *C. vernalis* usually has the anterior margin of the seminal receptacle convex, but may have an anterior margin with a slight indentation. I found both types in one culture (see Figs. 53 & 54). Variation in shape of the seminal receptacle has been a source of confusion contributing to the unwarranted formation of new species. The seminal receptacle of *C. vernalis* having a median indentation of the anterior border is essentially of the same form as one of *C. viridis* having the anterior margin only slightly concave (see Figs. 6 & 53). It would be difficult to give distinct definitions of form for the receptacles of these two species.

Notwithstanding that *C. vernalis* is extremely variable in form, as far as we know it is more so than any other copepod, there are, nevertheless, a number of clear distinctions between *vernalis* and *viridis*. The more striking differences may be summarized:

a. *C. viridis*, a large, robust, heavy-bodied species, is slow in movement and slow in development; while *C. vernalis*, a smaller, light-bodied, very active species, completes its life cycle in 1/2 to 1/3 the time required for *C. viridis*.

b. *C. viridis* lacks the outward extensions of the postero-lateral angles of the dorsum of the next to the last thoracic segment, which are usually prominent in *C. vernalis*.

c. The inner margins of the furcal rami are hairy in *C. viridis*, but not in *C. vernalis* (see discussion of this character above).

d. The innermost terminal furcal seta is longer than the ramus and over twice as long as the outermost terminal seta in *C. viridis*, while this seta is shorter than the ramus and not twice as long as the outermost terminal seta in *C. vernalis*.

e. *C. viridis* has the inner terminal spine of the endopod 3 of P_4 always definitely longer than the outer, while *C. vernalis* has these two spines almost the same size, either inner or outer being the longer.

f. *C. viridis* has the inner lateral spine of segment two of P_5 small and just distal to the middle of the segment, while *C. vernalis* has this spine larger and more apical.

TABLE 1.—Types of armature of rami of swimming feet (P 1-4) of *Cyclops viridis*, *C. vernalis* and related species. Spines indicated by large figures, setae by small figures.

TYPE	SPECIES	APPENDAGE	OUTER RAMUS									INNER RAMUS								
			SEG. 1		SEG. 2			SEG. 3				SEG. 1		SEG. 2			SEG. 3			
			OUTER SIDE	INNER SIDE	OUTER SIDE	END	INNER SIDE	OUTER SIDE	END	INNER SIDE		OUTER SIDE	INNER SIDE	OUTER SIDE	END	INNER SIDE	OUTER SIDE	END	INNER SIDE	
A	C. VIRIDIS (JURINE) C. GIGAS CLAUS C. GIGAS LATIPES LOWNDES C. MAGNUS MARSH C. VERNALIS FISCHER C. CAROLINIANUS N. SP. C. VENUSTOIDES COKER C. EXILIS COKER C. BISCUPIDATUS CLAUS C. BISETOSUS REHRBURG[6] C. CRASSICAUDIS SARS[6]	P1	1	1	1		1	2	2	2		0	1	0		2 or 1[5]	1	1 + 1	3	
		P2	1	1	1		1	2	1 + 1	3		0	1	0		2	1	1 + 1	3	
		P3	LIKE P2																	
		P4	1	1	1		1	2	1 + 1	3		0	1	0		2	1	2	2	
B	C. VERNALIS FISCHER C. CAROLINIANUS N. SP.	P1	1	1	1		1	3	2	2		0	1	0		2	1	1 + 1	3	
		P2	1	1	1		1	3	1 + 1	3		0	1	0		2	1	1 + 1	3	
		P3	LIKE P2																	
		P4	1	1	1		1	3	1 + 1	3		0	1	0		2	1	2	2	
C	C. VERNALIS FISCHER FORMA BREVISPINOSUS HERRICK[7] FORMA ROBUSTUS SARS[7]	P1	1	1	1		1	3	2	2		0	1	0		2	1	1 + 1	3	
		P2	1	1	1		1	3	1 + 1	3		0	1	0		2	1 or 1[7]	1 + 1	3	
		P3	1	1	1		1	3	1 + 1	3		0	1	0		2	1	2 or 1 + 1[7]	3	
		P4	1	1	1		1	3	1 + 1	3		0	1	0		2	1	2	2	

[5] The armature of C. bisetosus and C. crassicaudis differs from that of the other species having 1 spine instead of 2 on the outer side of segment 3 of inner ramus of P 2 and by having a spine and a seta instead of 2 spines at the apical end of inner ramus of P 3 (Herrick, 1895 & Sars, 1918).

C	FORMA BREVISPINOSUS HERRICK																	
	FORMA ROBUSTUS SARS[7]	P3	1	1	1		1	3	1+1	3	0	1	0		2	1	2m 1+1[7]	3
		P4	1	1	1		1	3	1+1	3	0	1	0		2	1	2	2

7 The armature of P 4 in this male differs from that of the other specimens in that it consists of a spine at the outer side of segment 3 of inner ramus of P 2 and by having a spine and a seta instead of 2 spines at the apical end of inner ramus of P 3 (Herrick, 1895 & Sars, 1918).

D	C. VENUSTUS NORMAN & SCOTT C. CAPILLATUS SARS	P1	1	1	1		1	3	2	3	0	1	0		2	1	1+1	3
		P2	1	1	1		1	3	1+1	4	0	1	0		2	1	1+1	3
		P3	LIKE P2															
		P4	1	1	1		1	3	1+1	4	0	1	0		2	1	2	2
E	C. NANUS SARS	P1	1	1	3	2	3	-	-	-	0	1	1	1+1	3	-	-	-
		P2	1	1	1		1	2	1+1	3	0	1	1	1+1	4	-	-	-
		P3	1	1	1		1	2	1+1	3	0	1	0		1	1	1+1	3
		P4	1	1	1		1	2	1+1	3	0	1	0		2[8]	1	2	2
F	C. VARICANS SARS C. BICOLOR SARS	P1	1	1	3	2	3	-	-	-	0	1	1	1+1	3	-	-	-
		P2	1	1	3	1+1	4	-	-	-	0	1	1	1+1	4	-	-	-
		P3	LIKE P2															
		P4	1	0	2	1+1	4	-	-	-	0	1	1	2	3	-	-	-
G	C. STRENUUS FISCHER C. SCUTIFER SARS	P1	1	1	1		1	3	2	3	0	1	0		2	1	1+1	3
		P2	1	1	1		1	3	1+1	4	0	1	0		2	1	1+1	3
		P3	1	1	1		1	2	1+1	4	0	1	0		2	1	1+1	3
		P4	1	1	1		1	2	1+1	4	0	1	0		2	1	2	2
H	C. VICINUS ULJANIN C. INSIGNIS CLAUS	P1	1	1	1		1	2	2	3	0	1	0		2	1	1+1	3
		P2	1	1	1		1		1+1	4	0	1	0		2	1	1+1	3
		P3	LIKE P2															
		P4	1	1	1		1	2	1+1	4	0	1	0		2	1	2	2

8 Proximal seta small.

CYCLOPS VIRIDIS (Jurine) 1820

(Figs. 1-23)

Monoculus quadricornis viridis Jurine 1820, His. des Monocl. 46.
Cyclops viridis Fischer 1851.
Cyclops brevicornis (not Nicolet) Claus 1857.
Cyclops clausi (not Lubbock or Poggenpol) Heller 1871.
Cyclops gigas (not Claus) Brady 1880.
Cyclops viridis (part.) Schmeil 1892.
Cyclops viridis europeus Herrick 1895.
Cyclops vulgaris Sars 1918.
Cyclops teres Wilson 1925?
Cyclops viridis Kiefer 1929.
Cyclops viridis Gurney 1933.

Specimens of *C. viridis* collected or reared at Paris, France, by Coker, were dissected, studied and drawn in the preparation of this account. Among these were descendants of one pair reared severally at temperatures 8°, 15°, 19°, and 28° C. as well as some collected from natural pools. Specimens of *C. viridis* from Raintor Meadows, Durham County, England, (collected by G. S. Brady) were loaned by the U. S. National Museum. These are indistinguishable from the Paris collection.

It is still somewhat uncertain whether the true European type of *C. viridis* appears in America. Chambers (1912) says that he had specimens of it from pools near Edgewater, New Jersey. They were 2 to 3 mm. in length and had hairy inner margins of the furcal rami, spine formula of exopods 3 of P_{1-4} 2, 3, 3, 3, typical fifth feet; typical seminal receptacles, and a chromosome number of 12, which is the number found by Haecker and Braun (1909) for *C. viridis*.

Marsh (1920) in his "Discussion of the *viridis* Group" says that the true *C. viridis* seems to be very rare in North America, and that he found the species in collections made near Green Bay, Wisconsin, and in a collection from Polk County, Florida. He states that these were typical in the armature of P_{1-4} and in the form of P_5 and the seminal receptacle.

That records of Chambers and Marsh do not definitely establish the occurrence of *C. viridis* in American waters is because the lack of essential details in descriptions and drawings make it impossible to tell whether they had specimens of *C. magnus* Marsh, *C. gigas* Claus, *C. gigas latipes* Lowndes, *C. donnaldsoni* Chappuis, or *C. viridis* (Jurine). Herrick's *C. ingens* may have represented the typical *C. viridis*, but we cannot know (see pp. 27, 29). Although the specimens have been sought from different parts of the country, no copepod which could be assigned to *C. viridis* (Jurine), as it is now defined, has been found.

Length of adult females, in my collection, varies from 1.61 to 2.33 mm. Gurney (1933) gives the length as 1.5 to 3 mm., while Sars (1918) and Lilljeborg (1901) give it as 1.9 mm., and Kiefer (1929) gives it as 1.5 to 2.5 mm. Coker (1933) discusses the relation of size in *C. viridis* to the temperature at which they developed. Those reared at lower temperatures are larger

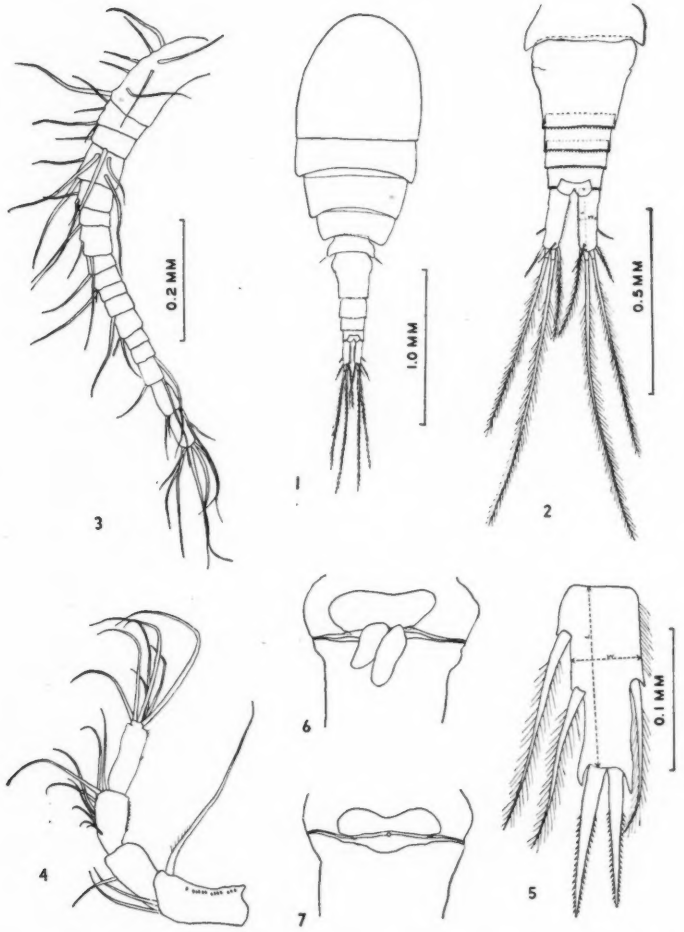


PLATE 1. Figs. 1-7. *Cyclops viridis* (Jurine) from Paris, France. 1. Adult female. 2. Part of last thoracic segment, abdominal segments, and furcal rami of an adult female, showing method of measuring furcal ramus. 3. First antenna of female. 4. Second antenna of female. 5. Endopod 3 of P4, showing method of measuring length and width of segment. 6. Seminal receptacle with attached spermatophores. 7. Seminal receptacle. (4, 6 and 7 drawn to the same scale.)

than those reared at high temperatures. Coker (1933) reared two lines of *C. viridis* at known temperatures. His results were as follows:

Females

Temperature (centigrade)	Line 5 No. of Examples	Line 5 Mean Length (mm.)	Line 6 No. of Examples	Line 6 Mean Length (mm.)
7°–13°	14	2.01	7	2.27
14°–15°	6	1.80	51	2.20
18°–19°			4	1.75
28°–30°	2	1.68	3	1.69

Males Line 6

Temperature (centigrade)	No. of Examples	Mean Length (mm.)
7°–13°	4	1.42
14°–15°	11	1.49
18°–19°	7	1.34
28°–30°	8	1.24

Extremes of Length in mm.

Females

	Longest	Shortest
Line 5	2.24 (14°-15°)	1.53 (14°-15°)
Line 6	2.45 (7°-10°, 14°-15°)	1.55 (28°-30°)

Males

	Longest	Shortest
Line 6	1.59 (14°-15°)	1.21 (28°-30°)

An exception is noted in the case of the males in line 6, reared at 7° to 13°, which average smaller than those reared at 14° to 15°. The amount of food was thought to influence the size only to a slight extent, if at all.

In general body appearance, the species is robust. The posterior borders of the abdominal segments, except the last, are usually serrated, although in some examples this serration is inconspicuous. The posterior border of the last abdominal segment is armed with tiny spines. None of the thoracic segments (except the last which is slightly produced laterally) have outwardly produced, postero-lateral angles of the dorsa. The furcal rami are moderately slender, being 4 to 6 times as long as wide, according to Gurney (1933), and with a quotient of length into width of 0.220 to 0.346, in my specimens. Temperatures at which my specimens (two specimens for each of the three lower temperatures given, one specimen for the highest temperature, and all descended from one pair) were reared, and quotients of length into width of furcal rami are as follows: 8°, 0.220 and 0.268; 15°, 0.233 and 0.257; 19°, 0.273 and 0.293; 28°, 0.346 (see Figs. 17-23). These measurements suggest that, to some extent, the slenderness of the furcal rami of *C. viridis* may vary, according to the temperature at which the animal is reared, as previously found for *C. vernalis*, by Coker (1934), where those reared in colder water had more slender furcal rami than those reared in warmer water. The small outer lateral seta is inserted at a point 70% to 75% of the distance from base to distal end of the furcal ramus. Our measurements on specimens reared at different temperatures

showed that, with respect to position of this seta, there is no correlation with the temperature. The relative terminal setal lengths, innermost to outermost, of the furcal ramus give ratios such as: 2.25: 7.17: 5.17: 1 and 2.30: 7.17: 507: 1. The innermost terminal seta is much longer than the furcal ramus.

The first antennae consist of 17 segments (see Fig. 3), but Coker (1934) has reared an example with 18 segmented antennae (the seventh segments being divided). The first antennae extend about to the posterior border of the first segment of the body. The aesthete or sensory club of the distal end of the 12th segment extends to the middle of the 14th segment.

P_{1-4} have inner and outer rami of three segments. The spine formula of the third segments of the exopods of P_{1-4} is 2, 3, 3, 3. Type A, in Table 1, gives the complete armature of the swimming feet. An indentation of the outside of the first segment of the endopod of P_4 may or may not be present, as in *C. vernalis* (see Fig. 58).

The third segment of the endopod of P_4 is more than twice as long as wide, according to Gurney (1933). The quotient of length into width varies from 0.375 to 0.509 in my specimens. Specimens of the same line, reared at the following temperatures (2 examples for each temperature given, with the exception of 28°, for which temperature only one example was available) had the following quotients of length into width: 8°, 0.440 and 0.464; 15°, 0.413 and 0.484; 19°, 0.418 and 0.509; 29°, 0.375. Only a study of substantial numbers would demonstrate whether or not there is a correlation of proportions of this segment with temperature. A specimen collected from a natural pool had the quotient of length into width of this segment 0.386. Quotient of length of segment into length of longest terminal spine in this segment varies from 0.843 to 0.901, and no suggestion of correlation with temperatures is noted. Quotient of length of shortest spine into length of longest spine varies from 1.08 to 1.40, but most are about 1.08. Again there appeared no suggestion of correlation with the temperatures at which the specimens were reared. The inner terminal spine is always longer than the outer, according to available literature and as found in my collections. The setae of endopod 3 of P_4 do not extend to the ends of the terminal spines.

P_5 consists of a broad basal segment with an outer seta and a smaller slender second segment with an apical seta, and a small inner spine inserted just distal to the middle of the segment. This small spine may or may not be jointed (see Figs. 15 & 16).

The seminal receptacle has a concave anterior border. It may be deeply indented or only slightly indented (see Figs. 6 & 7).

For more complete descriptions see Schmeil (1892), or Gurney (1933).

The North American distribution of *C. viridis* cannot be given here because of the uncertainty of the records (see above and the discussion of *C. ingens* Herrick).

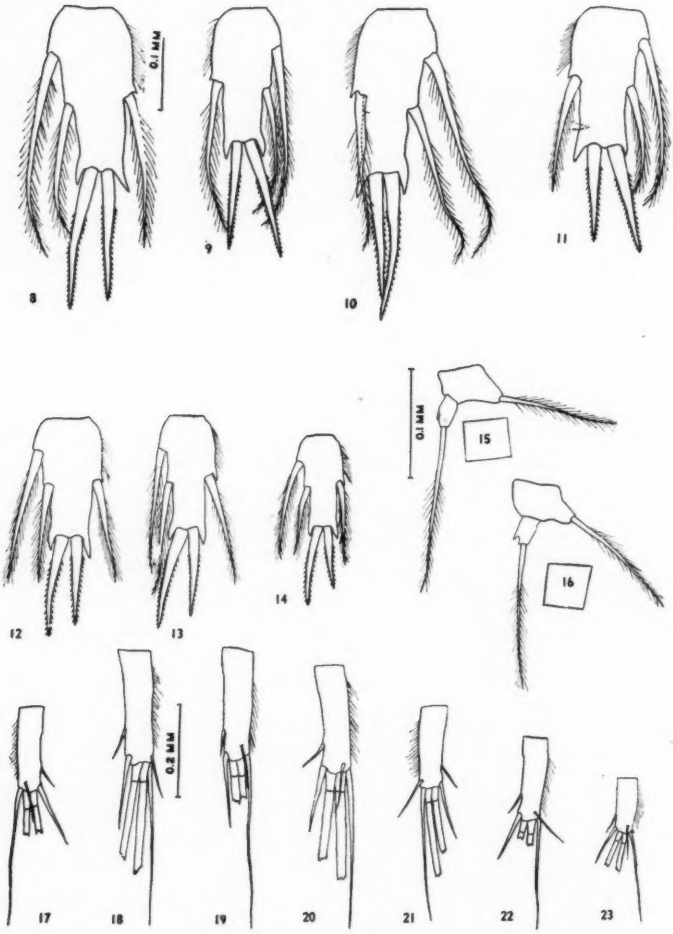


PLATE 2. Figs. 8-23. *Cyclops viridis* (Jurine) from Paris, France. Endopod 3 of P4, P5, and furcal rami, from females of the same line. 8 & 9. Endopod 3 of P4; from females reared at 8° C. 10 & 11. Endopod 3 of P4; from females reared at 15° C. 12 & 13. Endopod 3 of P4; from females reared at 19° C. 14. Endopod 3 of P4; from female reared at 28° C. (8-14 drawn to the same scale.) 15 & 16. P5. 17 & 18. Furcal rami from females reared at 8° C. 19 & 20. Furcal rami from females reared at 15° C. 21 & 22. Furcal rami from females reared at 19° C. 23. Furcal ramus from female reared at 28° C. (15-23 drawn to the same scale.)

CYCLOPS MAGNUS Marsh 1920
(Figs. 24-35)

Cyclops magnus Marsh 1920, Report Canad. Arct. Exp. 7(J):1-75.

Type in the U. S. Nat. Museum No. 58782.

Specimens of this species, loaned by the U. S. National Museum, were collected on Chantry Island (Bernard Harbor), Northwest Territories, Canada, by the Canadian Arctic Expedition on June 17, 1916. They were identified by C. D. Marsh, who based this species on them or others collected at about the same time. According to Marsh, *C. magnus* was taken in collections from Collinson Point, Alaska; Cape Bathurst, Chantry Island, Bernard Harbor, Dolphin and Union Strait, Northwest Territories, Canada.

The females are very large, robust copepods, having a body length, excluding the furcal setae, of about 2.4 mm., although one example had a length of only 1.90 mm. Marsh (1920) gives the range of length as 1.85 to 2.4 mm. The posterior borders of the abdominal somites (except the last abdominal, which has its posterior border armed with tiny spines) are coarsely serrated. No evidence of outwardly produced postero-lateral angles of the dorsum of the next to the last thoracic segment was found in any of the Chantry Island specimens. The 5th thoracic segment is slightly produced laterally. Furcal rami are of moderate length, usually about four times as long as wide (FW/FL: 0.218 to 0.296), corresponding to *C. viridis*. The small lateral seta is inserted at about the beginning of the distal fourth (73% to 75% of the distance from base to tip of the ramus). Inner margins of the furcal rami are hairy as in *C. viridis*. Relative lengths of the terminal setae, innermost to outermost, of the furcal ramus give ratios such as 1.41: 6.58: 5.17: 1 and 1.5: 6.68: 5.83: 1. The innermost terminal seta is slightly shorter than the furcal ramus (unlike *C. viridis*).

The 17-segmented first antenna is much like that of *C. viridis*, extending about to the posterior margin of the first segment of the body. The aesthete inserted at the distal end of segment 12 extends beyond the middle of segment 14, but generally not to the distal end of this segment. The first through the four pair of swimming feet have rami of 3 segments. The spine formula of the terminal segments of the exopods of P_{1-4} is, as in *C. viridis*, 2, 3, 3, 3. The complete armature of the rami of the swimming feet is of Type A (see Table 1 for descriptions of types of armature). The terminal segment of endopod of P_4 is rather stubby—having a quotient of length into width of 0.39 to 0.414. Quotient of length of segment into length of the longest terminal spine is 0.74 to 0.79, while the quotient of length of shortest terminal spine into longest terminal spine is 1.19 to 1.21. The outer terminal spine is in all my specimens longer than the inner (see Figs. 26 & 27). In this respect *C. magnus* differs from the European type of *C. viridis*, which has the inner terminal longer (see Fig. 5).

P_5 is indistinguishable from that of *C. viridis*.

Some large copepods, which are undoubtedly *C. magnus*, were secured from Churchill, Manitoba (sent to Dr. R. E. Coker by H. Elliott McClure

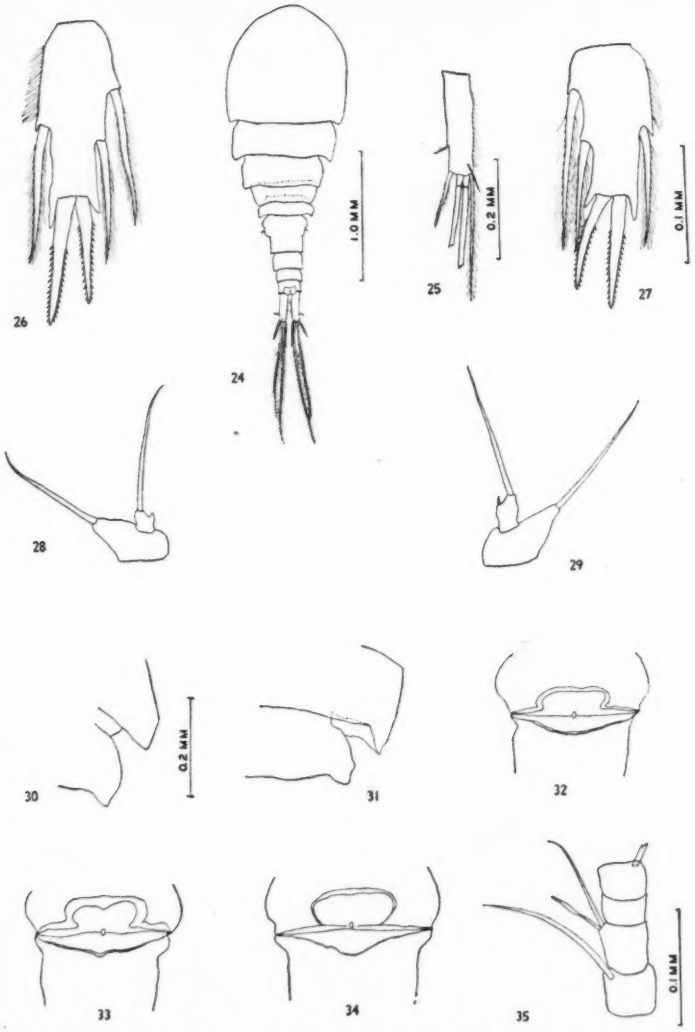


PLATE 3. Figs. 24-35. *Cyclops magnus* Marsh. 24. Adult female from Chantry Island, Bernard Harbor, N. W. T., Canada. 25. Furcal ramus of female from Churchill, Manitoba. 26. Endopod 3 of P4 of female from Bernard Harbor. 27. Endopod 3 of P4 of female from Churchill. 28. P5 of Bernard Harbor female. 29. P5 of Churchill female. (26-29 drawn to same scale.) 30 & 31. Right side of dorsum of 3rd and 4th thoracic segments of Churchill female. 32 & 33. Seminal receptacles of Churchill females. 34. Seminal receptacle of Bernard Harbor female. 11th, 12th, 13th and 14th segments of first antenna of Churchill female. (30-35 drawn to same scale.)

of Ames, Iowa). They averaged about the same size as the Chantry Island *C. magnus*. Some of the Churchill specimens seemed to have slightly outwardly produced postero-lateral angles of dorsum of the next to the last thoracic segment (see (Figs. 30 & 31), but this is not true of the Chantry Island *C. magnus*. (Such a difference often exists between *C. bicuspidatus* and its variety —*C. bicuspidatus thomasi*.)

The furcas of the Churchill and Chantry Island copepods, respectively, are generally similar, but they differ in the terminal setae, chiefly in the relative length of the innermost setae. The Churchill copepods have relative terminal setal lengths, innermost to outermost, which give ratios such as 22: 6.13: 5.20: 1 and 1.88: 6.41: 5.41: 1, the innermost terminal seta being somewhat longer than the furcal ramus (see Fig. 25). The aesthete of the 12th segment of the antenna is slightly longer in the Churchill specimens.

The third segment of the endopod of P_4 is slightly stubbier in the Churchill *magnus* than that of the Chantry Island *magnus* (quotient of length into width being 0.447 to 0.464, in the Churchill *magnus* and 0.39 to 0.414 in the Chantry Island *magnus*. The terminal spines are, however, alike in both lots—the relative lengths being alike and the outer spine always the longer (see Figs. 26 & 27).

The differences mentioned above are the only ones found. Therefore, Churchill's *magnus* should be considered a variant of Marsh's *C. magnus*.

Obviously, *C. magnus* resembles *C. viridis*, in most respects. Examination of the descriptions of the two species reveals the following differences: On the average, *C. magnus* is larger than *C. viridis;* the relative lengths of the terminal furcal setae differ in the two species; in *C. viridis* the innermost terminal furcal seta is much longer than the furcal ramus, but in *C. magnus* it is either shorter than the ramus (Chantry Island *magnus*) or but little longer (Churchill *magnus*); the terminal spines of segment 3 of endopod P_4 are longer in relation to length of segment in *C. viridis* than in *C. magnus*—the inner spine being the longer in *C. viridis*, and the outer the longer in *C. magnus;* finally the anterior margin of the seminal receptacle in *C. viridis* is concave, while that in *C. magnus* is nearly always convex, but sometimes, slightly indented in the middle. Actually the seminal receptacle of *C. viridis* and *C. magnus* seem to grade into each other, some of the receptacles of *C. viridis* being only slightly indented in the middle, as in a few cases of *C. magnus* (see Figs. 6, 32, 33).

Some of the differences between *C. magnus* and *C. viridis* seem of little significance. *C. magnus* may well be merely a variety of *C. viridis*. But, since they can always be separated by the relative lengths of the terminal spines of the endopod of P_4 and the length of the innermost terminal, furcal seta relative to the others and to the length of the ramus, they should be treated as distinct species until there is further evidence of intergradation.

C. magnus seems to be an exclusively northern species, as it has been collected only in arctic Alaska, Northwest Territories, Canada, and Churchill, Manitoba (see above).

CYCLOPS GIGAS LATIPES Lowndes 1927

(Figs. 36-44)

Cyclops latipes Lowndes 1927, Ann. Mag. Nat. Hist., s. 9, **19**:266, Figs.
Cyclops latipes Kiefer 1929.
Cyclops gigas latipes Gurney 1933.

Three specimens, undoubtedly of this subspecies, were collected at Sycamore Flats, Chapel Hill, N. C., on November 28, 1927 by Coker. They were the only ones available for study, and, indeed, seem to be the only copepods thus far taken in North America and assignable to the subspecies *latipes*. It is uncertain whether Herrick's *C. ingens* and several records of the European type of *C. viridis* are really *C. gigas latipes*. Early descriptions did not give sufficient details for accurate identification.

Kiefer (1929) gives the length of the female *latipes* as 1.9 mm., and Gurney (1933) gives it as 1.85 to 2.25 mm. The Chapel Hill specimens measure 2.4225 mm. and 2.48 mm. The third specimen was already dissected, when secured by me; so that no length measurement could be obtained. In general body appearance, *latipes* is robust, but generally with abdominal segments more slender than those in *C. viridis* (see Figs. 2 & 37). The posterior margins of abdominal segments, except the last, are serrated, although this serration is not very conspicuous. The posterior border of the last abdominal segment is armed with small spines. The fifth thoracic segment in the Chapel Hill specimens has slightly outwardly produced, postero-lateral angles of the dorsa, though not as pronounced as shown by Gurney (1933). The 4th thoracic segment is not laterally produced. Furcal rami have approximately the same proportions as those of *C. viridis* and are not as slender as those of *C. gigas* as described and figured by Gurney (1933). Gurney (1933) gives the length of the furcal ramus of *latipes* as 5 to 6 times the width, but the quotient of length into width of the Chapel Hill specimens is 0.233 to 0.280. The small outer lateral seta is inserted at a point 75% to 77% (67% to 75%, according to Gurney, 1933) of the distance from the base to the distal end of the furcal ramus. Inner margins of the furcal rami are hairy. Relative terminal setal lengths, innermost to outermost, are about 1.87: 5.74: 4.16: 1. Few relative length measurements of setae could be secured since only one specimen had all these terminal setae unbroken. The innermost terminal seta in all three specimens is not quite twice as long as the outermost one, but longer than the furcal ramus (see Figs. 37 & 38).

The 17-segmented first antenna does not extend beyond the 1st segment of the body. The aesthete at the distal end of the 12th segment extends only to the distal end of the 13th segment in the Chapel Hill specimens (see Fig. 40), while Gurney (1933, Fig. 1592) shows this aesthete as extending beyond the 13th segment.

Each of the rami of P_{1-4} is of three segments. The spine formula of the third segment of the endopods of P_{1-4} is 2, 3, 3, 3. The complete armature of the swimming feet is given in Table 1, Type A.

The length of the 3rd segment of P_4 endopod is either twice or less than

twice the width, according to Gurney (1933) and the quotient of length into width of the Chapel Hill specimens is from 0.435 to 0.468. The quotient of length of the segment into length of the longest terminal spine is from 0.967 to 1.19, and the quotient of length of shortest spine into length of longest spine is 1.21 to 1.22. The inner terminal spine is longer than the outer. The setae of endopod 3 P_4 extend beyond the ends of the terminal spines (see Fig. 41).

P_5 is much like that of *C. viridis* (see Figs. 39 & 42).

The seminal receptacle has a concave anterior margin and resembles that of *C. viridis* (see Figs. 43 & 44).

Descriptions indicate that the main difference between *C. latipes* and *C. gigas* are: the greater slenderness in the swimming feet and furcal rami of *C. gigas* and the greater relative lengths of the setae of the third segment of the endopod of P_4 of *C. latipes*. These setae extend beyond the terminal spines of their segment in *C. latipes*, but do not extend to the ends of the terminal spines in *C. gigas*. Such slight differences do not warrant making *C. gigas* and *C. latipes* separate species; so that it seems best to consider *C. latipes* a subspecies of *C. gigas*, as did Gurney (1933). Only crossing experiments can determine whether *latipes* should be considered a distinct species.

C. latipes, usually larger than *C. viridis*, differs from it in having generally more slender abdominal segments, in having the setae of endopod 3 P_4 extending beyond the terminal spines in that segment, and in having different relative lengths of the terminal furcal setae. Lowndes (1932) attempted to cross *C. latipes* with *C. viridis*, but without success.

C. latipes is much larger than *C. donnaldsoni* as described, and differs from that species in having a more slender endopod 3 of P_4, more slender furcal rami, and different relative lengths of the terminal furcal setae. Descriptions of the two species show that they are quite alike in many respects.

Apparently *C. gigas latipes* is not common in America since the only definite locality from which specimens have been collected is Chapel Hill, N. C. It is possible that some of the records of *C. viridis* (Jurine) and *C. ingens* Herrick are really records of *latipes* (see our descriptions of these species).

DISCUSSION OF HERRICK'S C. INGENS

The original description of *Cyclops ingens by* C. L. Herrick (1882) leaves considerable doubt about its status. Later (1884) its author regarded it as identical with *C. gigas*, which in turn was treated as a large variety of *C. viridis;* finally (1895) *C. ingens* was interpreted as a rare size variation of *C. viridis americanus* (now called *C. vernalis americanus*). Obviously Herrick confused *C. viridis* with *C. vernalis* throughout his writings, since he apparently failed to see European specimens and to check carefully the descriptions of these very distinct species.

The length of the female *C. ingens*, excluding the furcal setae, is given as occasionally reaching 3.0 mm. No *C. vernalis* (*C. americanus*) is known to

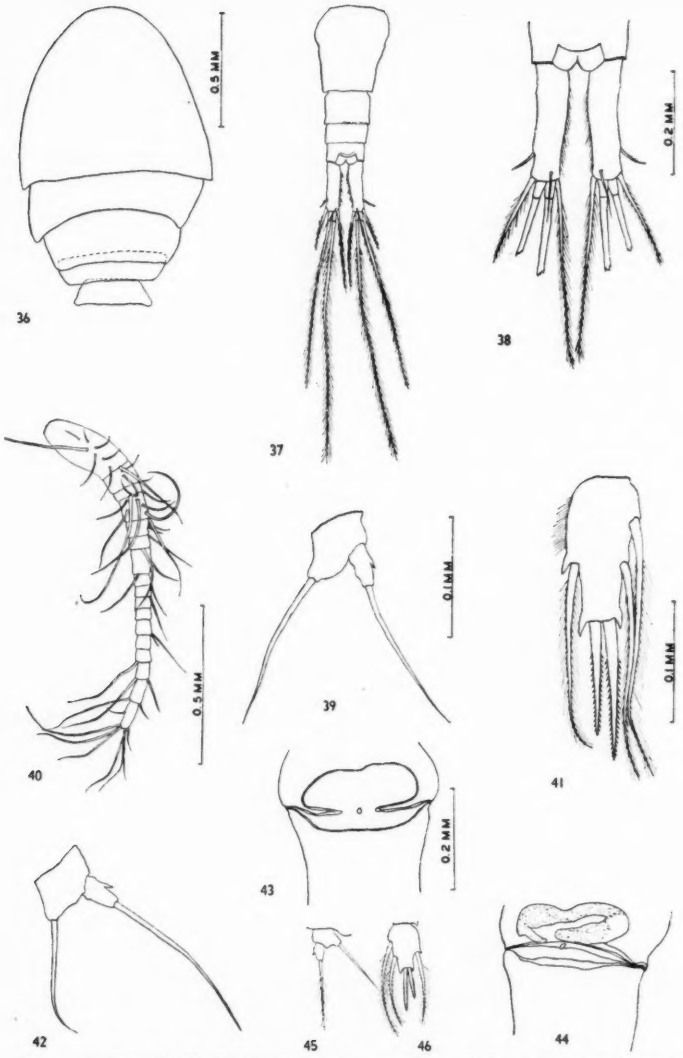


PLATE 4. Figs. 36-46. 36-44 drawn from examples of C. *gigas latipes* Lowndes from Chapel Hill, N. C. 36. Cephalothorax and 2nd, 3rd, 4th and 5th thoracic segments of female, slightly mashed by cover-slip. 37. Abdominal segments and furcal rami of female. Same scale as 36. 38. Furcal rami. 39. P5. 40. First antenna. 41. Endopod 3 of P4. 42. P5. Same scale as 41. 43 & 44. Seminal receptacles. 45. P5 of *Cyclops donnaldsoni* Chappuis. (After Chappuis, 1929.) 46. Third segment of Endopod of P4 of *Cyclops donnaldsoni* Chappuis. (After Chappuis, 1929.)

attain such a length (2.0 mm. being the maximum size recorded—Wolf, 1905). Herrick's figures of *C. ingens* are poor; no hairs are shown on the inner margins of the furcal rami, but he may have overlooked them. My measurements from Herrick's drawing of the furcal rami and their setae give the following data, which are of little value, because of the probable inaccuracy of the drawing. Quotient of length into width of one ramus is about 0.2, of the other ramus—0.267; relative terminal setal lengths, innermost to outermost, of the two rami is 1.35: 4.7: 3.4: 1 and 1.81: 6: 4.5: 1; innermost terminal seta is about as long as furcal ramus; position of outer lateral seta is at a point about 70% of the distance from base to distal end of the ramus. These data, if correct, would indicate a fairly close relationship as to furcal structure between *C. ingens* and *C. gigas latipes* from Chapel Hill, N. C. (see description of *C. gigas latipes*, pp. 26, 27).

Herrick draws the seminal receptacle of *C. ingens* with a concave anterior margin and with a close resemblance to that of *C. viridis* and *C. gigas*. His figure of P_5 is like P_5 of *C. viridis* and *C. gigas;* the inner lateral spine of segment two is without a joint.

Forbes (1897) states that *C. ingens* is the only described American form closely resembling the European *C. viridis*. Forbes was well acquainted with European *C. viridis*, since he had secured specimens from Sars and Schmeil, and had made accurate drawings of them. Forbes also had copepods which he called *C. levis* (from an unpublished description in 1870 by S. A. Forbes) or *C. ingens* Herrick. He stated that *ingens* had the inner border of the furcal rami hairy as on the European *viridis*, that *ingens* differed from the European *viridis* only in size, and that it differed from the *C. gigas* sent by Sars only in small details in the shape of the two segments of P_5. Forbes concluded that *gigas* and *ingens* are only forms of a typical *C. viridis*.

The armature of the swimming feet is not mentioned in any literature. Since there can be found neither description nor drawings of the endopod of P_4, it cannot be determined definitely whether *C. ingens* is the same as *C. magnus, C. gigas, C. gigas latipes* or *C. viridis*. Such information as is available points to the correctness of Sar's conclusion, that *C. ingens* is a synonym of *C. gigas* or more specifically, I should say, of *C. gigas latipes*.

CYCLOPS DONNALDSONI Chappuis 1929

(Figs. 45-46)

Cyclops donnaldsoni Chappuis 1929, Bull. Soc. Sci. Cluj. (Roumanie) **4**(pt. 2e):51-57.
Cyclops donnaldsoni Kiefer 1929.

The species was described from specimens taken from Donnaldson Cave in Indiana, and, so far as I can ascertain, has only been found there and possibly in Algeria.

Since no specimens of the species were available for study the following description is taken from the original by Chappuis.

The length of female, exclusive of furcal setae, is 1.45 mm. (or 2.- mm. including furcal setae). Greatest width is given as 0.45 mm. The posterior

borders of the abdominal segment are toothed. No mention is made of outwardly-produced postero-lateral angles of the dorsa of the last two thoracic segments. The furcal rami are relatively short, 3 times longer than broad, or quotient of length into width, 0.333. The lateral seta is inserted at a point about 75% of the distance from base to distal end of the furcal ramus. The inner margin of each furcal ramus is described as hairy, but sparingly so. The relative lengths of the terminal setae of the furcal ramus, innermost to outermost seta, are 3: 7: 4.4: 1. Comparison of length of innermost terminal seta with length of furcal ramus is not given.

Turning to the appendages, the first antenna is of the *C. viridis* or *C. vernalis* type, with 17 segemnts, and not extending beyond the posterior border of the first segment of the body. The aesthete or club, at the end of the 12th antennal segment extends to the distal end of segment 14. The rami of all the swimming feet, 1 through 4, are of 3 segments. Unfortunately, the spine formula of the terminal segments of the exopods of swimming feet, 1 through 4, is not given. The terminal segment of endopod of P_4 is short (see Fig. 46), 1.4 times longer than wide, or with a quotient of length into width of 0.71, as mentioned in the text; but our measurements of Chappuis' figure, following the method given in Fig. 5, result in quotient of length into width of 0.605. Quotient of length of segment into length of longest terminal spine is not given, but a measurement of Chappuis' figure gives 1.0, or equal lengths of spine and segment. The inner spine is said to be 1.25 times longer than the outer one; again, however, a measurement of Chappuis' figure gives a different result—inner spine 1.36 times longer than the outer. The setae of terminal segment of endopod of P_4 extend beyond the end of the longest terminal spine, as in *C. gigas latipes*. P_5 is like that of *C. viridis*, or *C. gigas*, the inner spine of segment 2, being small and near the middle of the segment (see Fig. 45).

The seminal receptacle was not in good enough condition to be described.

This description seems to place *donnaldsoni* very close to *C. gigas latipes*, from which it differs in being smaller, more stubby in most of its parts, and in having different relative lengths of the terminal furcal setae (see description of *C. gigas latipes*). In these respects it resembles *C. viridis* closely. Chappuis suggests that *C. donnaldsoni* seems to occupy a position intermediate between *C. viridis* and *C. latipes* (now called *C. gigas latipes*); we believe, however, that both *C. gigas* and *C. gigas latipes* are more closely related to *C. viridis* than is *C. donnaldsoni*.

In 1929, Chappuis sent Kiefer some copepods from a well at Ain Ourka (not far from Ain Sefra), Algeria. Keifer (1930) said these copepods were very similar to *C. donnaldsoni* Chappuis except in the proportions of endopod 3 of P_4. In these African copepods this segment is longer in proportion to width and the terminal spines are more nearly equal in length and are shorter in proportion to length of the segment than in the American *donnaldsoni*. Our measurement of Kiefer's figure gives the quotient of length of segment into width as 0.514 (slightly stubbier than in *C. viridis*), quotient of length

of segment into length of longest terminal spine as about 0.9, and quotient of length of shorter terminal spine into length of longer terminal spine as about 1.21. The seta do not extend to the distal ends of the terminal spines in the African copepods, but extend considerably beyond these spines in the American *donnaldsoni* (see Fig. 46). Kiefer (1930) considered these Algerian copepods a subspecies of *C. donnaldsoni* Chappuis and named them *C. donnaldsoni algericus* although he indicated that they were possibly a distinct species. As in the case of many other closely related copepods, only breeding experiments will determine the relationship between these African and American copepods.

C. donnaldsoni, as described by Chappuis, has been collected only from Donnaldson Cave in Indiana.

CYCLOPS VERNALIS Fischer 1853

(Figs. 47-58)

Cyclops vernalis Fischer 1853, Bull. Soc. Nat. Moscou, **26**(1):90, Figs.
Cyclops elongatus Claus 1863.
Cyclops lucidulus (?C. L. Koch) Sars 1863.
Cyclops robustus Sars 1863.
Cyclops insectus S. A. Forbes 1882.
Cyclops parcus Herrick 1882.
Cyclops viridis (not Jurine) Cragin 1883.
Cyclops uniangulatus Cragin 1883.
Cyclops brevispinosus Herrick 1884.
Cyclops vernalis Schmeil 1892.
Cyclops americanus Marsh 1893.
Cyclops parcus Marsh 1893.
Cyclops brevispinosus Marsh 1893.
Cyclops viridis americanus Herrick 1895.
Cyclops vernalis E. B. Forbes 1897.
Cyclops viridis var. *insectus, brevispinosus* E. B. Forbes 1897.
Cyclops brevicornis (not Nicolet or Claus) Scourfield 1898.
Cyclops vernalis Kiefer 1929.
Cyclops robustus Kiefer 1929.
Cyclops vernalis Gurney 1933.
Cyclops viridis Pine 1934.
Cyclops vernalis Coker 1934.

C. vernalis is one of the most common, and one of the most variable and most frequently misidentified species of Cyclops in North America.

We have examined specimens from Paris, France (collection of Coker); from various bodies of water in Orange County, North Carolina; from Cattaraugus County, New York; from Mystic Lake, Banff, Alberta, Canada (from G. C. Carl); from Lake Patzcuaro (Michoacan) Mexico (sent by Dr. B. F. Osorio Tafall); from an alkali marsh, Stafford County, Kansas; and from Nunivak Island, Alaska. The copepods from the last two localities were loaned by the U. S. National Museum, and had been identified by Marsh as the species—*C. americanus*. Live specimens were readily available from water around Chapel Hill, N. C.

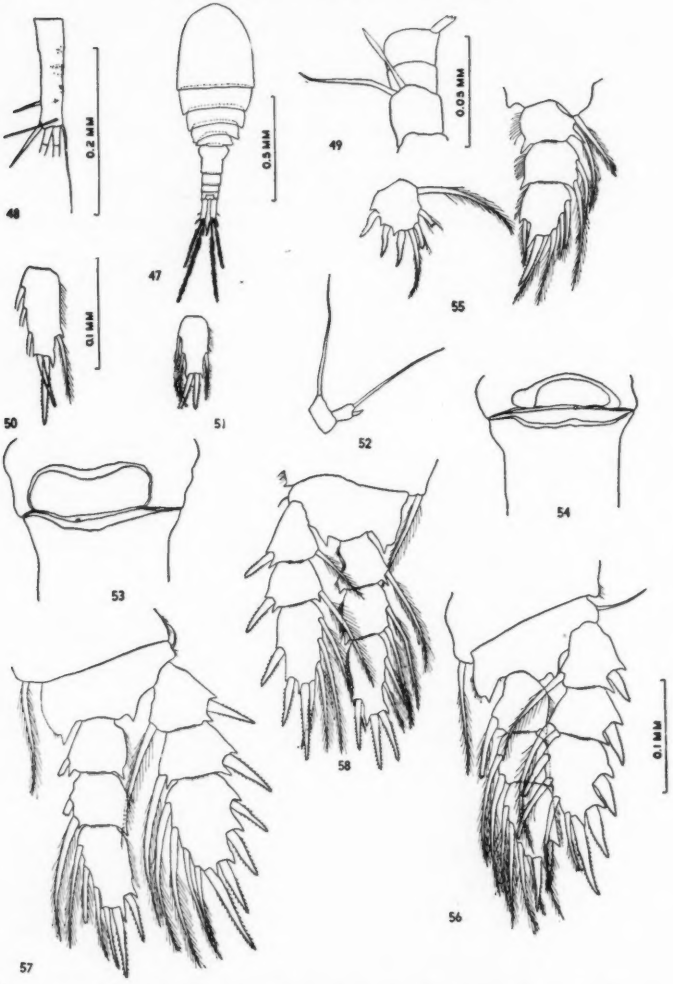


PLATE 5. Figs. 47-58. *Cyclops vernalis* Fischer from Chapel Hill, N. C. 47. Adult female, small example. 48. Furcal ramus; not spinules on surface of integument. 49. Aesthete and 12th, 13th and 14th segments of first antenna of adult female. 50. Endopod 3 of P3 of male, showing crossed terminal spines. There may be an inner terminal seta instead of an inner terminal spine, crossing the outer terminal spine. 51. Endopod 3 of P4 of female, showing seta instead of spine on outer side. 52. P5. 53 & 54. Variations in form of the seminal receptacle. (50-54 drawn to same scale.) 55. Endopod and third segment of exepod of P1 of an abnormal female. 56. P2 of same copepod. 57. P3 of same copepod. 58. P5 of same copepod. (55-58 drawn to same scale).

The females vary in length from 0.99 to 1.83 mm. excluding the furcal setae; according to the literature, they sometimes reach 1.80 mm. (Gurney 1933 and Coker 1934) and even 2.0 mm. (Wolf 1905). These animals are only moderately robust in general body appearance.

Posterior borders of the first three abdominal segments are not serrated, or are very slightly serrated in the adult, but the last abdominal segment has its posterior border armed with small spines. The last two thoracic segments usually have prominent outwardly-produced postero-lateral angles of the dorsa (see Fig. 47), although in rare cases, such protrusions are seen with difficulty. Marsh strangely failed to note these protrusions, which are prominent in some specimens that were identified by him as *C. americanus*.

Furcal rami are of moderate length, generally having a quotient of length into width of 0.200 to 0.250. The small outer lateral seta is inserted at a point about 75% of the distance from base to distal end of the ramus. Inner margins of the furcal rami are not hairy.

Gurney (1933, in fig. 1603) shows tiny spinules on the surface of the furcal rami (particularly on the inner margins). These spinules are present on many of our examples (see Fig. 48) and should not be confused with hairs. The relative lengths of the terminal furcal setae, innermost to outermost, give ratios such as 1.25: 7: 5.41: 1 and 1.81: 8.75: 5.06: 1. The outermost seta may either be a short spine, as in the *brevispinosus* form of *C. vernalis*, a slender seta, or an intermediate between the two extremes. E. B. Forbes (1897) shows by his figure 1, Plate XI, how greatly this outer spine or seta can vary. The innermost terminal seta is shorter than the furcal ramus.

The first antennae are usually of 17 segments, but sometimes, by division of the 7th, or rarely by the division of the 4th (Coker 1934) there are 18 segments. Animals, with one first antenna of 17 segments, and the other of 18 segments, have been found by Schmeil (1892) and Coker (1934). Usually the first antenna does not extend beyond the first segment of the body. The aesthete or club inserted at the distal end of the 12th segment (13th in the 18 segmented antenna) is fairly long, extending beyond the distal end of the following two segments.

Rami of P_{1-4} are 3 segments. The spine formula of segment 3 of the exopods of P_{1-4} may be 2, 3, 3, 3 or 3, 4, 4, 4 or otherwise. Frequently the spine formula on one side differs from that on the other side. The complete armature of the swimming feet is given in Table 1 in the descriptions of types of armature. *C. vernalis* may have Type A, Type B, Type C, or Type C with more of the setae modified to form spines, or a mixture of the types. Type A armature is characteristic of the *parcus* type of *C. vernalis*, and is the most common armature in animals reared at high temperatures. Type B armature is characteristic of the *americanus* type of *C. vernalis* and is most common in animals reared at lower temperatures. Type C is characteristic of the *brevispinosus* type of *C. vernalis* and is common in limnetic, cold water animals. Type C is also characteristic in the *robustus* type of *C. vernalis*. Figs. 55 through 58 show one of the many variants in the C type of armature, legs 2 and 4 being abnormal. Any of the three types of armature can be secured in

offspring of parents showing the A type, or B type, or C type of armature (Coker 1934 and Yeatman 1943). The armature of the swimming feet may be an hereditary character, with manifestation modified by environmental conditions. An indentation of the outer side of segment one of the endopod of P_4 can be seen in Fig. 58. This indentation may be pronounced, slight, or absent. Forbes (1897) seems to have been the first to notice this indentation.

The quotient of length into width of the terminal segment of P_4 varies from 0.431 to 0.530 in the specimens we have examined (0.43 to 0.55, according to Coker 1934). The quotient of length of segment into length of the longer of the two terminal spines is 0.640 to 0.777, but usually between 0.750 and 0.760. Quotient of shorter terminal spine into longer terminal spine is 1.02 to 1.07 (for *C. viridis*, 1.08 to 1.40); in other words, these spines in *vernalis* are of very nearly the same length, either the inner or the outer spine may be longer. As can be seen, by the description of armature types (see Table 1), this terminal segment of endopod of P_4 can have either a spine or a seta on its outer border. The setae of this segment usually do not extend to the ends of the terminal spines.

P_5 is generally like that of *C. viridis*, but has the inner spine of segment two relatively larger, always jointed at the base, and nearly apical (see Fig. 52). Often this spine will have tiny spinules on it.

The shape of the seminal receptacle has been described by Schmeil (1892), Chambers (1912), Sars (1918), Marsh (1920) and others. Chambers pointed out that *C. parcus* has a seminal receptacle with a concave anterior margin. Both types can be found in the same culture of *C. vernalis* (see Figs. 53 & 54) in my specimens. Herrick, in his original description of *C. parcus*, states that it has a transversely oval seminal receptacle and mentions it as being very similar to that of *C. vernalis*. Marsh (1920) describes the anterior margin of the seminal receptacle of *C. americanus*, *C. parcus*, *C. brevispinosus* (all considered now to be forms of *C. vernalis*) as convex. Gurney (1933) says that the anterior margin of the seminal receptacle of *C. vernalis* is usually evenly arched, but that sometimes there is a median indentation. Actually there is very little difference between the forms of the seminal receptacle of a specimen of *C. vernalis* with a slight median anterior marginal indentation and that of *C. viridis* with anterior margin slightly concave (see Figs. 6 & 53). The form of the seminal receptacle is generally a good taxonomic character but, with respect to the two species under consideration (*C. vernalis* and *C. viridis*), no specific difference can be found.

A discussion of the confusion of and the differences between *C. vernalis* and *C. viridis* is given on pp. 8-15. See also pp. 37-40 for description of *C. carolinianus* which is structurally very close to *vernalis*.

C. vernalis is the most widely distributed of any American copepod of the *viridis-vernalis* group, being found in some form from arctic Alaska to southern Mexico and from the Atlantic to the Pacific Ocean. Almost no body of water of any size is without them.

DISCUSSION OF SOME COMMON FORMS OF C. VERNALIS

In order to assit the reader in distinguishing some of the so-called forms of *C. vernalis*, Table 2 was compiled. Like many authors (Sars, 1918; Coker, 1934, etc.), I am unable to distinguish *parcus* from *C. vernalis* as described by Sars. *Parcus* usually has shorter furcal rami, but even some of Herrick's specimens of *parcus* had these rami elongated, as in Sars' *C. vernalis*.

Americanus has often been separated from *C. parcus* by difference in spine formula of exopod 3 of P_{1-4}. That this spine formula often varies among members reared from eggs of the same egg sac, has been definitely established (Coker, 1934). Gurney (1933) considers *americanus* as a subspecies of *C. vernalis*. He says that the lateral extensions of the posterior angles of the dorsa of the last two thoracic segments are blunt and not nearly so prominent in *americanus* as in *C. vernalis*, that the innermost terminal furcal seta is about twice as long as the outermost terminal seta and nearly as long as the furcal ramus in *americanus*, while this inner seta is not much longer than the outer and about ½ the length of the ramus in *C. vernalis*. Herrick's elongated specimens of *parcus* have the innermost terminal furcal seta long, as in Gurney's *americanus* specimens, and Marsh (1893) described his *americanus* copepods as having the innermost and outermost terminal furcal setae nearly equal in length. Gurney (1933) also says that the seminal receptacle of *americanus* is of the same form as that of *C. vernalis*, but has a much broader hyaline border around the anterior end. The width of this hyaline border varies in our Chapel Hill, N. C., specimens (see Figs. 43 & 54, Fig. 53 being about like the seminal receptacles of *C. vernalis americanus* as figured by Gurney, 1933); so we can hardly see how *americanus* could be distinguished from *C. vernalis* by this character alone. We can find no real distinction between *C. americanus*, as described by Marsh, and *C. vernalis, as* described by Sars, and the best European writers (see Table 2).

Brevispinosus has been separated from *parcus* as more slender than the average *parcus* (though no more so than some of Herrick's elongate specimens of *parcus*), as having a different spine formula for exopod 3 of P_{1-4} (not significant), and as having spines in the place of setae on some parts of the appendages and on the furcal rami. *C. vernalis*, *parcus*, and *americanus* have all been supposed to have a seta on the outer side of endopod 3 of P_{1-4}, while *brevispinosus* has a spine on the outer side of endopod 3 of P_{3-4}. Also *brevispinosus* has 2 spines at the end of endopod 3 of P_3 instead of the spine and seta found in *C. vernalis*, *parcus*, and *americanus*, and even in *robustus*. The outermost terminal furcal seta of *C. vernalis*, *parcus* and *americanus* is replaced in *brevispinosus* by a very short, stout serrate spine. This latter character distinguishes *brevispinosus* from other forms of *C. vernalis*, although the terminal furcal setae of *robustus* are said to be unusually strong, or, in the words of Sars, "almost spiniform." The great slenderness of *brevispinosus* is most likely associated with its limnetic habitat, while replacement of setae by spines often occurs in offspring of *parcus*, of *americanus* or of *vernalis* (see later paragraph). (See also Lowndes, 1929, on *robustus* and *vernalis*.)

Robustus has been separated from *C. vernalis* (and *americanus*, as well)

TABLE 2.—Comparison of some of the so-called sub-species of *C. vernalis* Fischer.

PARTS COMPARED	C. VERNALIS FISCHER AS DESCRIBED BY SARS 1918	C. ROBUSTUS SARS AS DESCR. BY SARS 1918	C. PARCUS HERRICK AS DESCR. BY HERRICK 1895	C. BREVISPINOSUS HERRICK AS DESCR. BY HERRICK 1895	C. AMERICANUS MARSH AS DESCR. BY MARSH 1893
BODY LENGTH	1.40 - 1.50 MM.	1.20 MM.	1.40 - 1.50 MM.	1.0 MM.	1.20 MM.
POSTERO-LATERAL ANGLES OF DORSA OF 4 & 5 THORACIC SEGMENTS LATERALLY PRODUCED?	YES	YES	YES	NOT MENTIONED	NOT MENTIONED
GENERAL APPEARANCE OF BODY	COMPARATIVELY SLENDER	MORE ROBUST THAN C. LUCIDULUS	ABOUT LIKE C. VERNALIS	MORE SLENDER THAN THE USUAL PARCUS	NOT MENTIONED
FURCAL RAMI	RATHER LONG AND SLENDER, EQUALLING LENGTH OF LAST 3 ABDOMINAL SEGMENTS COMBINED	COMPARATIVELY SHORTER & LESS NARROW THAN IN VERNALIS, NOT ATTAINING LENGTH OF LAST 3 SEGS. COMBINED	USUALLY RATHER SHORT, BUT SOME EXAMPLES WITH RAMI 6 TIMES AS LONG AS BROAD	MORE ELONGATE THAN IN THE USUAL PARCUS, ABOUT 4.5 TIMES AS LONG AS BROAD	ABOUT 3 TIMES AS LONG AS BROAD
TERMINAL FURCAL SETAE	SETA OF INNER CORNER VERY THIN & SOMEWHAT LONGER THAN THAT OF THE OUTER (MORE SO THAN IN ROBUSTUS)	UNUSUALLY STRONG ALMOST SPINIFORM, SETA OF INNER CORNER ONLY SLIGHTLY LONGER THAN THAT OF THE OUTER CORNER	INNERMOST SETA 1/4 LONGER THAN OUTERMOST; INNERMOST SETA OF ELONGATED EXS. 1/3 LONGER THAN OUTER & NEARLY AS LONG AS RAMUS	OUTERMOST SETA REPLACED BY A VERY SHORT, STOUT, SERRATE SPINE - SHORTER THAN THE INNERMOST SETA & 1/3 AS LONG AS RAMUS	INNERMOST AND OUTERMOST SETAE SHORT, SLENDER, PLUMOSE, & NEARLY EQUAL IN LENGTH
SPINE FORMULA OF EXOPOD 3 OF P1-4	2, 3, 3, 3 OR 3, 4, 4, 4	3, 4, 4, 4	2, 3, 3, 3	3, 4, 4, 4	3, 4, 4, 4
ARMATURE OF OUTER SIDE OF ENDOPOD 3 OF P1-4	P1-4 = SETA	P1 = SETA P2-4 = SPINE	P1-4 = SETA	P1 & 2 = SETA P3 & 4 = SPINE	P1-4 = SETA
ARMATURE OF END OF ENDOPOD 3 OF P3	1 SPINE & 1 SETA	1 SPINE & 1 SETA	1 SPINE & 1 SETA	2 SPINES	1 SPINE & 1 SETA
HABITAT	COMMON IN SHALLOW POOLS & DITCHES	A BOTTOM FORM AT MARGIN OF LARGE LAKES	LIVES IN STAGNANT POOLS	LIMNETIC IN LAKES, BUT SOMETIMES LITTORAL	LITTORAL IN LAKES & STAGNANT POOLS

as being more robust and having many setae replaced by spines. The outer side of endopod 3 of P_{2-4} has a spine instead of a seta and its terminal furcal setae are very strong and "almost spiniform." It differs from *brevispinosus* in being considerably more robust, and with rather short furcal rami, in having a very strong outer terminal furcal seta instead of a spine, and in having a very slight difference in armature of P_2 and P_3: the outer side of endopod 3 of P_2 of *robustus* is armed with a spine instead of a seta, and the end of endopod 3 of P_3 is armed with a spine and a seta rather than 2 spines. *Robustus* is a bottom feeder at the edge of lakes (Sars 1918) and is not limnetic. Robust body and stubby furcal setae are often associated with Cyclopoid copepods living in a littoral habitat.

As mentioned before, this discussion of forms of *C. vernalis*, as they must now be termed, is based, as far as possible, on the original descriptions. These forms are not consistently distinct enough to be important, as many variants occur which are difficult to assign to any of these entities. Specimens of *vernalis* are known which have even more of the setae replaced by spines than either *brevispinosus* or *robustus*. For example, I have a specimen of the spine formula of exopod 3 of $P_{1-4} = 3, 3, 4, 3$ whose endopods are armed as in *brevispinosus* (see Figs. 55-58). Although its furcal rami are moderately slender, the outermost terminal side has a seta in place of the spine characteristic of *brevispinosus*. Variants are very frequent in *C. vernalis*, and should not be considered abnormalities.

Coker (1934) found that most of the specimens, developing at intermediate temperatures, could be classified as *C. vernalis*, as described by Sars; occasional specimens, reared at high intermediate temperatures, as *robustus* of Sars; many specimens, reared at low temperatures (10° C.), as *americanus;* and many specimens, reared at temperatures above 25° C., as *parcus*. Environmental factors other than temperature probably influence the external structure of *C. vernalis*.

From a single female of *C. vernalis* I reared offspring indistinguishable from *parcus, americanus,* and *brevispinosus*. Whether the characters that separate these forms are influenced by environmental conditions or by genetic factors, must be decided by breeding experiments. For a brief discussion of Chambers' work on the chromosome numbers of *americanus, parcus,* and *brevispinosus* see pp. 11, 12.

At present it seems best to omit any attempt to classify specimens of *C. vernalis* to subspecies or varieties, because any of the forms mentioned in this discussion may develop from the eggs of any form of *C. vernalis* and in all combinations of characters. One may use the term *forma* if desired, but the number of formae, if precisely described, would be very high.

Cyclops carolinianus, n. sp.

(Figs. 59-72)

Type in the U. S. National Museum, No. 78889.

Many individuals of this species have been collected from a pool at Mann's Chapel (April 1941 and Feb. 6, 1942) and another on Mason Farm

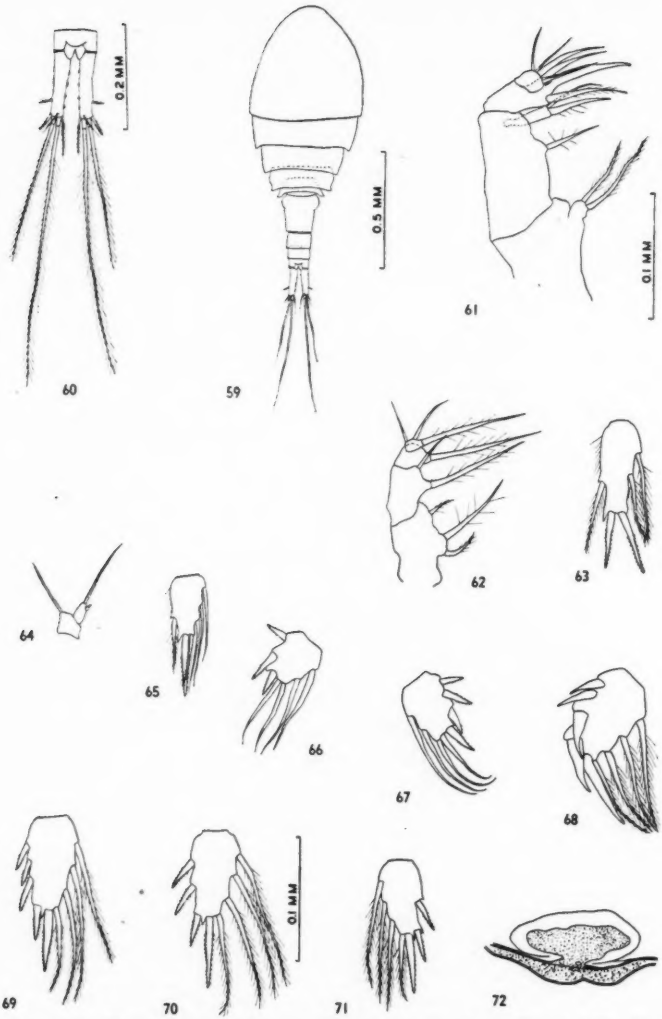


PLATE 6. Figs. 59-72. *Cyclops carolinianus, n. sp.*, from Chapel Hill, N. C. 59. Adult female. 60. Last abdominal segment and furcal rami of female. 61. Anterior maxilliped. 62. Posterior maxilliped. 63. Endopod 3 of P4 of female. 64. P5. 65. Endopod 3 of P3 of male. (61-65 drawn to same scale.) 66 & 67. Exopods 3 of P1 of abnormal female. 68. Exopod 3 of P2 of abnormal female. (Shape as well as armature of this segment was abnormal on both sides). 69. Exopod 3 of P4 of abnormal female. 70 & 71. Exopod 3 of P4 of normal females, showing variation in the number of spines on outer side. 72. Seminal receptacle. (66-72 drawn to same scale.)

(Feb. 21, 1942). Both of these localities are near Chapel Hill, North Carolina.

Body length of the female varies from 0.80 to 1.50 mm., but is usually about 1.12 mm. Thus it averages smaller than *C. vernalis* which it resembles very closely (see Fig. 59). Posterior borders of the first three thoracic segments of the adult are not serrated or are very slightly serrated, and the posterior border of the last abdominal segment is armed with tiny spines. As in *C. vernalis,* the postero-lateral angles of the dorsa of the last two thoracic segments are prominently produced (see Fig. 59).

Furcal rami are generally about 5 times as long as broad (see Fig. 60) although quotients of length into width such as 0.176 and 0.31 are obtained. The small outer lateral seta is attached at a point about 75% of the distance from base to distal end of the ramus. Inner margins of the furcal rami have tufts of small hairs (see Fig. 60) which can be easily overlooked. The presence of these hairs is the chief point of distinction between this species and *C. vernalis* which lacks hairs on the inner margins of its furcal rami. One should not confuse the tiny spinules often present on the surface of the inner margins of the furcal rami of *C. vernalis* (see Fig. 48) with hairs. Also, algae, basteria, and remains of protozoa (chiefly the stalked ciliata) are sometimes mistaken for hairs. Relative lengths of the terminal furcal setae, innermost to outermost, give ratios such as 1.6: 10: 6: 1 and 2: 12: 7: 1. The outermost terminal seta is usually short and moderately slender. The innermost terminal seta is always shorter than the furcal ramus.

First antennae are of 17 segments and extend about to the hind border of the cephalothorax. The aesthete at the distal margin of the 12th segment extends beyond the distal end of the 14th segment, as in *C. vernalis.* The second antennae, mandibles, maxillae, anterior maxillipeds (see Fig. 61), and posterior maxillipeds (see Fig. 62) resemble those of *C. vernalis.* Rami of P_{1-4} are of 3 segments and as in *C. vernalis,* the spine formula of the terminal segment of the exopods can be 2, 3, 3, 3 or 3, 4, 4, 4 or otherwise. We have examples with the spine formula of one side differing from that of the other. One female has a 3, 5, 4, 5 formula on her left side and a 4, 4, 4, 4 formula on her right side, extra spines being present and setae not being replaced by spines (see Figs. 66-69). The setal formula of these segments is 4, 4, 4, 4. Type A and Type B in Table 1 give the complete armature of the swimming feet, but, as shown above, the number of spines on the terminal segments of the exopods may vary.

Quotient of length into width of endopod 3 of P_4 varies from 0.36 to 0.45 and quotient of length of this segment into lengths of the longer of the two terminal spines is 0.60 to 0.753. Quotient of length of shorter terminal spine into length of longer terminal spine is 1.10 to 1.18, usually the inner spine but sometimes the outer being the longer. All the hundreds of specimens which were collected or reared in the laboratory have had a seta instead of a spine on the outer side of endopod 3 of P_4. The setae of this segment do not extend to the end of the terminal spines (see Fig. 63).

P_5 and the seminal receptacle are like those of *C. vernalis* (see Figs. 64 & 72).

The male resembles the *C. vernalis* male as it lacks hairs on the inner margins of its furcal rami. It is interesting that among Cyclopoid copepods, the male of some species lacks the ornamentation that is so characteristic of its female; for example, the male *Eucyclops serrulatus* lacks the serrations on the outer sides of its furcal rami.

Forbes (1897) said that the large *C. ingens* Herrick (see p. 27) was the only form of the *viridis* group with the inner margins of its furcal hairy and that the inner margins of the furcal ramus of smaller forms of this group "is never ciliate [hairy], though in rare cases the whole inner aspect of the stylet ramus seems to be set with the shortest of hairs, only visible on account of their points of attachment." We are not sure whether Forbes saw short hairs as in *C. carolinianus* or tiny spinules so often present on the furcal rami of *C. vernalis* (see Fig. 48). We suspect that they were the latter since the hairs of *carolinianus* are visible, though inconspicuous. Forbes described *insectus* S. A. Forbes (which he considered the same as *americanus* Marsh and *parcus* Herrick) as lacking hairs on the inner margin of the furcal rami.

From our description and the accompanying figures, one can see that the only definite structural difference between *C. carolinianus* and *C. vernalis* is the presence of small inconspicuous hairs on the inner margins of the furcal rami of the former. Indeed, I considered *carolinianus* merely a subspecies of *vernalis* until attempts to cross-breed them failed. 50 crosses (female *vernalis* with male *carolinianus* and vice-versa) were attempted, all under conditions favorable for the breeding and rearing of both species, as experience had shown. There was little sexual isolation or preference isolation, for many females with spermatophores attached to the seminal receptacle opening were observed. Four *vernalis* females fertilized by *carolinianus* males had large egg sacs full of eggs that appeared to be segmenting; these egg sacs, however, were always dropped in a few hours and the eggs would disintegrate. Here is an example of an insignificant somatic difference being associated with a genetic difference that inhibits interbreeding. Attempts are being made to determine whether the diploid number of chromosomes for *carolinianus* is 10, as for *vernalis*.

I have reared hundreds of specimens of *carolinianus* and *vernalis* under various conditions of temperature, salinity, light, food, etc., but the females of the former always have hair on the inner margins of the furcal rami and the females of the latter always lack them. Because of this small structural difference and the inability of the two copepods to interbreed, there is no choice but to describe *carolinianus* as a new species.

Carolinianus has been collected only from pools about Chapel Hill, North Carolina, but it is possible that some of the specimens of *parcus* and *americanus* collected by Forbes, Marsh, and others were really of this species, the hairs on the furcal rami being unnoticed.

CYCLOPS EXILIS Coker 1934
(Figs. 73-78)

Cyclops exilis Coker 1934, Journ. Elisha Mitchell Sci. Soc. **49**(2). 1934.

Type in the U. S. National Museum, No. 69104.

This species has been taken at Chapel Hill, N. C., and at the Allegheny School of Natural History, Cattaraugus County, N. Y., egg-bearing females occurring in considerable numbers at both places, according to Coker (1934). Six examples, 3 from each of the above localities, were examined in the preparation of this account, supplementing the original description.

Body length (omitting the furcal setae) of the female varies from 0.78 to 0.85 mm. in the Chapel Hill collection, and is about 0.88 mm. in the New York collection, according to Coker (1934). Specimens from both localities, that we measured, are from 0.75 mm. to 0.78 mm. in length. In general body appearance, *C. exilis* is like a dwarfed *C. vernalis* (see Fig. 73). The 4th and 5th thoracic segments have outwardly-produced postero-lateral angles, which are not as conspicuous as in *C. vernalis*. As in *C. venustoides* Coker, the anal plate extends more posteriorly than that of *C. vernalis* (see Figs. 47 & 75).

Posterior margins of the abdominal segments (except the last, which has its posterior margin armed with tiny spinules) are not serrated, or but very slightly so.

Quotient of length into width of furcal rami in our specimens is about 0.31 to 0.40 (0.38 to 0.42, Coker, 1934). The small outer lateral seta is inserted at a point about 66% to 69% of the distance from base to apex of the ramus. Inner margins of the rami lack hairs. Relative terminal setal lengths, innermost to outermost, give ratios such as 1.45: 12.7: 7.1: 1 and 1.92: 15.4: 8: 1. Generally the innermost terminal furcal seta was almost twice as long as the outermost one, and longer than the ramus.

The first antennae are of 11 or 12 segments, usually the former (see Fig. 76). Coker (1934) had a single specimen with the second joint incomplete, so that the antenna appeared to consist of 10 segments, when viewed along the posterior margin. In the 11-segmented antenna, the third segment is fairly long, having failed to divide to make the short third and longer fourth segments found in antennae of 12 or 17 segments. These antennae extend about to the posterior margin of the first segment of the body and bear an aesthete at the middle of the 8th segment (9th in the 12-segmented antenna) that extends to the middle of the 9th segment (10th in the 12-segmented antenna). As in *C. venustoides*, this aesthete cannot always be seen.

The inner and outer rami of P_{1-4} are of three segments. Spine formula of the terminal segments of the exopods of P_{1-4} is 2, 3, 3, 3 and the setal formula is 4,4,4,4. Type A, Table 1, gives the complete armature of P_{1-4}. Quotient of length into width of endopod 3 of P_4 is 0.545 to 0.620, while the quotient of length of this segment into length of the longer of its two terminal spines is 1.0 to 1.06. The inner terminal seta is 1.76 to 1.87 times longer than

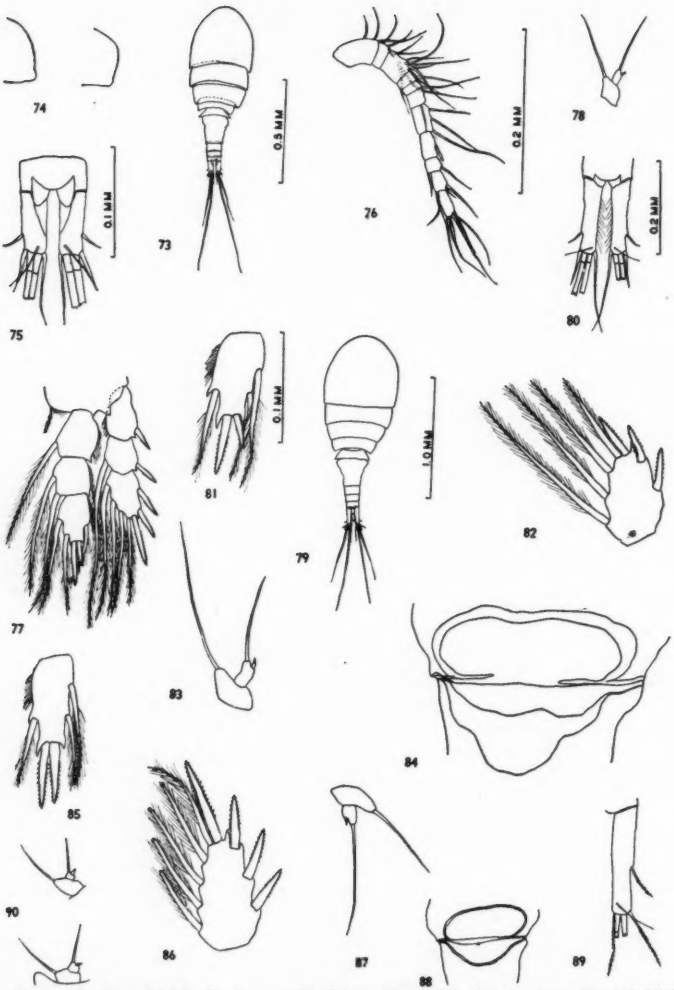


PLATE 7. Figs. 73-90. *Cyclops exilis* Coker. 73. Adult female from Chapel Hill, N. C. 74. Variation in form of the lateral margin of the dorsum of the 4th body segment. Same scale as 75. 75. Furcal rami and last abdominal segment of female from Chapel Hill, N. C. 76. First antenna of female from Cattaraugus County, New York. 77. P4 of female from Cattaraugus County, New York. Same scale as 75. 78. P5 of female from Chapel Hill, N. C. Same scale as 75. *Cyclops venustoides* Coker, from Chapel Hill, N. C. 79. Adult female. 80. Furcal rami of female. 81. Endopod 3 of P4. 82. Exopod 3 of P4. 83. P5. 84. Seminal receptacle. (81-84 drawn to same scale.) *Cyclops venustus* Norman and Scott, from Great Britain. 85. Endopod 3 of P4. 86. Exopod 3 of P4. 87. P5. (85-87 drawn to same scale as 81.) 88. Seminal receptacle. Same scale as 80. *C. capillatus* Sars. (After Marsh, 1920). 89. Furcal ramus. 90. P5 showing variation in form.

the outer. The seta (particularly the inner setae) of endopod 3 of P_4 extend beyond the distal ends of the terminal spines (see Fig. 77).

P_5 is similar to that of *C. venustoides* and *C. vernalis*, but its distal segment is often slightly broader than that of the former (see Figs. 78 & 83).

The seminal receptacle is not clear in our specimens, but seems to be like that of *C. venustoides*.

C. exilis differs from the closely-related *C. venustoides* by being noticeably smaller in size, by having the postero-lateral angles of the 4th thoracic segment outwardly produced, by having the posterior margins of the abdominal segments not serrated, or very slightly so, by having more stubby furcal rami, by lacking hairs on the inner margins of the furcal rami, by usually having 11 segments to each first antenna, and only occasionally 12 as in *C. venustoides*, and by having the inner terminal spine of endopod 3 of P_4 much longer than the outer, rather than the outer much longer than the inner, as in *C. venustoides*.

C. michaelseni Mrazek, as described by Kiefer (1929) is like *C. exilis*, in having the first antennae of 11 segments, P_5 like that of *C. vernalis*, the innermost terminal furcal seta nearly twice as long as the outermost one, and very stubby furcal rami. *C. michaelseni* differs from *C. exilis* in having the lateral furcal seta more proximally placed and a different form of seminal receptacle. The seminal receptacle of *michaelseni* consists of a large transversely oval anterior portion with a raised margin and a small posterior portion with a sinuous margin, but the seminal receptacle of *exilis* seems to be like that of *venustoides* (see p. 45). There may be other differences, but we are unable to get many data on *C. michaelseni* since only 2 females have been collected and these were taken on the Falkland Islands.

C. kieferi Chappuis, as described by Chappuis (1925) and Kiefer (1926, 1929) has the first antennae of 11 segments, endopod 3 of P_4 like that of *exilis*, and anal plate that extends far back, but its innermost terminal furcal seta is shorter than the outermost one and very much shorter than the ramus instead of being almost twice as long as the outermost seta and longer than the ramus, as in *C. exilis*. The seminal receptacle of *kieferi* is transversely oval in form, the anterior and posterior portions being about equal in size.

C. reductus Chappuis, as described by Chappuis (1925) and Kiefer (1929) also has the first antennae of 11 segments, but the rami of the first 3 pairs of swimming feet are of two segments, instead of three.

C. michaelseni, *C. kieferi*, and *C. reductus* are placed in the same subgenus (Subgenus Acanthocyclops) as *C. vernalis* and have not been reported from North America. Concerning these copepods and *exilis*, Coker (1934, p. 281) says, "only further breeding experiments could determine the exact status of the several forms here considered, whether they are all species or only ecological variants of one species."

We know very little of the distribution of *C. exilis* in America, but at present it has been collected only in Cattaraugus County, New York, and Orange County, North Carolina.

CYCLOPS VENUSTOIDES Coker 1934

(Figs 79-84)

Cyclops venustoides Coker 1934, Jour. Elisha Mitchell Sci. Soc. **49**:(2). 1934.
Cyclops pilosus Kiefer 1934.
Cyclops venustoides Kiefer 1935.

Type in the U. S. National Museum, No. 69103.

About ten specimens of *C. venustoides* were examined in the preparation of this account. All were collected in the vicinity of Chapel Hill, N. C.

Body length, exclusive of furcal setae, of the adult female, varies in available specimens from 0.82 to 1.56 mm. (1.17 to 1.56 mm. for those collected in nature, and 1.01 to 1.13 mm. for those reared in the laboratory, according to Coker, 1934). The general body appearance is much like that of *C. vernalis*, but the 4th thoracic segment does not have its posterior margins laterally produced. The 5th thoracic segment has its posterior margins laterally produced, although not so prominently, as in *C. vernalis*. The genital segment is laterally expanded in the anterior portion, but its posterior portion is hardly broader than the next abdominal segment (see Fig. 79). The anal plate extends further posteriorly than that of *C. vernalis* (see Figs. 47 & 80). Posterior margins of the abdominal segments (except the last, which has its posterior margin armed with tiny spinules) are conspicuously serrated.

Quotient of length into width of the furcal rami is about 0.25 to 0.333, according to Coker (1934) but specimens collected later have slightly more slender rami; quotient of length into width, 0.21 to 0.223. The small outer lateral seta is inserted at a point, about 67% to 76% of the distance from the base to the apex of the furcal ramus. The inner margins of furcal rami bear fine hairs, while the outer margins show a slight notch (often with a tiny spine) about 1/3 of the distance from the base (see Fig. 80). Relative terminal furcal setal lengths, innermost to outermost, give ratios such as 2.12: 10.9: 7.19: 1 and 2.5: 13: 8: 1. The innermost terminal seta is slightly shorter than the ramus.

The first antennae are of 12 segments, the long 8th and 9th segments, not dividing to form, respectively, 8th to 11th and 12th to 14th segments as they do in the 17-segmented first antennae of *C. vernalis*. The antennae extend about to the posterior margin of the first segment of the body), and at the middle of the 9th segment of each is an aesthete that extends to the middle of the 10th segment. This aesthete is usually not easy to see.

The swimming feet have inner and outer rami of three segments. Spine formula of the terminal segments of exopods of P_{1-4} is 2,3,3,3; the setal formula of the same segments is 4,4,4,4. Type A, Table 1, gives the complete armature of P_{1-4}. In the specimens measured, quotient of length into width of endopod 3 of P_4 is 0.48 to 0.553 (0.54 to 0.66, and 0.51 in one case, according to Coker, 1934).

Quotient of length of endopod 3 of P_4 into length of the longer of its

two terminal spines, is about 0.73 to 0.81. The outer terminal spine of this segment is about 1.22 to 1.74 times longer than the inner. The setae of endopod 3 of P_4 extend beyond the distal ends of the terminal spines.

P_5 is like that of *C. vernalis*. Its basal segment is about twice as wide as its distal segment, and bears a seta on its outer side, while the distal segment is rather slender and bears an apical seta and an inner lateral spine that is near the apex (see Fig. 83).

The seminal receptacle has a transversely oval anterior portion, that may have the middle of its anterior margin slightly concave, and a more dorsal posterior portion (see Fig. 84).

C. venustoides resembles *C. vernalis* Fischer in general body form and in structure of P_5. It differs from *C. vernalis* (1) in not having the postero-lateral angles of the dorsa of the 4th thoracic segment laterally produced, (2) in having the posterior margins of the abdominal segments conspicuously serrated, (3) in having the anal plate extending more posteriorly (see Figs. 47 & 80) , (4) in having the inner margins of the furcal rami hairy, (5) in having the first antennae of 12 instead of 17 segments, (6) in having the lengths of the two terminal spines of endopod 3 of P_4 more unequal, (7) in having the setae of endopod 3 of P_4 extending much beyond the ends of the terminal spines, (8) and in having the posterior portion of the seminal receptacle slightly different (see Figs. 54 & 84). Coker has found important physiological differences between *C. venustoides* and *C. vernalis* (see Jour. Elisha Mitchell Sci. Soc. 49:(2). 1934).

Specimens of *C. venustus* Norman and Scott (1906) (see Figs. 85-88) sent to Dr. R. E. Coker by Dr. R. Gurney from Great Britain were examined. *C. venustoides* resembles *C. venustus* in having the posterior margins of the abdominal segments conspicuously serrated, the anal plate extending fairly far back, fine hairs on the inner margins of the furcal rami, the first antennae of 12 segments, the proportions of endopod 3 of P_4 about the same, and an apparently similar seminal receptacle. There are several differences, some of which are important. *C. venustus* has the spine formula of exopod 3 of P_{1-4} —3,4,4,4 instead of 2,3,3,3 (not necessarily an important taxonomic difference), the setal formula of exopod 3 of P_{1-4}—5,5,5,5 instead of 4,4,4,4 (a very important difference that separates these two species, at a glance, under the microscope), the inner terminal spine of endopod 3 of P_4 longer than the outer and their inequality in length not as great as in *C. venustoides*, the setae of endopod 3 of P_4 not extending to the ends of the terminal spines (see Fig. 85), and the distal segment of P_5 much more stubby than in *C. venustoides;* finally the surface of the cuticle of the abdominal segments practically always has transverse lines of scale-like elevations that are lacking in *C. venustoides*. Gurney (1933) says that neither the 4th nor 5th thoracic segments is laterally produced or pointed, but Coker (1934) gives one of the differences between *C. venustus* and *C. venustoides* as being the similarity of the 4th thoracic segment of *C. venustus* to that of *C. vernalis* (which has the postero-lateral angles prominently produced). Since these specimens are rather well-dissected, the shape of this segment can not be determined. *C. capillatus*, which is

described later in this paper, is more like *C. venustus,* in important structural features, than is *C. venustoides.*

A comparison of *C. venustoides* with the closely related *C. exilis* Coker is given at the end of the description of that species.

In June 1934, Kiefer described some copepods sent by E. G. Hutchinson from "Racebrook, Golf Course near Orange," Connecticut. To them he gave the name *Cyclops pilosus.* The description of these specimens conforms with Coker's description of *C. venustoides* and, in fact, Kiefer in 1935, after seeing the latter description, placed *pilosus* in the synonymy of *C. venustoides* since that name was about a month older than *pilosus.*

The only specimens of *venustoides* thus far collected have been from waters about Chapel Hill, North Carolina, and near Orange, Connecticut, but it will undoubtedly be found in other parts of North America, when more extensive collections are made.

CYCLOPS CAPILLATUS Sars, 1863

(Figs. 89 and 90)

Cyclops capillatus Sars 1863; Forh. Vid. Selsk. Christiana **1862**:248.
Cyclops capillatus Lilljeborg 1901.
Cyclops capillatus Kiefer 1929.

Since we could obtain no specimens of *C. capillatus;* the following description is taken mainly from Sars (1918), with a few additions from Kiefer (1929). So far, this species has been found at only one locality in North America—a lake at Konganevik (Camden Bay), Arctic Alaska, in a collection made June 26, 1914 (see Marsh, 1920). Only a few individuals were present. Apparently it is not common in Europe, having been taken only in Norway, Sweden, and Russia. The females are rather robust, and are of the general form of *C. viridis* (Jurine). Body length is about 1.80 mm. according to Sars (1918) and Kiefer (1929). The postero-lateral angles of the dorsa of the 4th and 5th thoracic segments are not laterally produced. The furcal rami are rather long and slender, about as long as the last three abdominal segments combined, according to Sars (1918), and about 4½ times as long as broad, according to Kiefer (1929). Inner margins of the furcal rami are not hairy. The outer lateral seta is attached at a point just distal to the middle of the furcal ramus (see Fig. 89). The inner of the two median terminal furcal setae is about ½ as long as the body. The innermost terminal furcal seta is slightly longer than the outermost one, and is shorter than the furcal ramus.

The first antennae are composed of 12 segments and extend about to the posterior margin of the first segment of the body. Inner and outer rami of P_{1-4} are of 3 segments that are moderately slender. The spine formula of the terminal segments of exopods of P_{1-4} is 3,4,4,4, while the setal formula of these exopods is 5,5,5,5. Type D, Table 1, gives the complete armature of P_{1-4} (which is the same type as that of *C. venustus* Norman and Scott). Endopod 3 of P_4 is very narrow, and at least as long as endopods 1 and 2 of

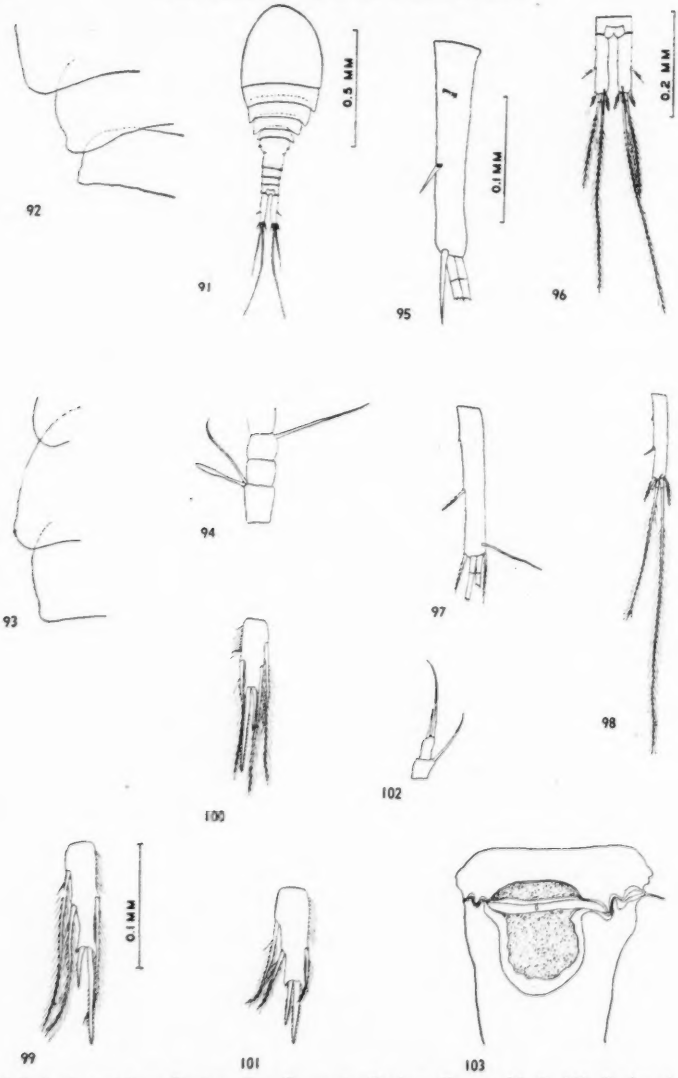
P_4 combined. Terminal spines of endopod 3 of P_4 are long and slender, the inner one slightly longer than the outer, and slightly shorter than the segment. The setae of this segment extend about to the tips of the terminal spines.

P_5 has a broad basal segment with an outer seta and a short, rounded distal segment that bears a seta at its distal end, and a small spine at about the middle of its inner side (see Fig. 90). According to the figures of this foot by Sars (1918), Marsh (1920), and Gurney (1933), it is like P_5 of *C. venustus*. The seminal receptacle has a transversely oval anterior portion, and a small posterior portion. It seems to be like that of *C. venustus* Norman and Scott and *C. venustoides* Coker.

Marsh's (1920) description of the Alaskan specimens corresponds very closely with that of Sars. These specimens have 12-segmented first antennae, furcal rami about 5 times as long as broad, and the outer lateral seta placed just distal to the middle of the furcal ramus. The posterior border of the last abdominal segment is armed with tiny spines. Spine formula of the terminal segments of the exopods of P_{1-4} is 3,4,4,4. Descriptions and figures of the fifth foot and seminal receptacles of the Alaskan specimens are like those described by Sars (1918). Body lengths of the females vary from 1.55 mm. to 2.55 mm.

C. venustus Norman and Scott agrees with *C. capillatus* in the armature of the swimming feet (spine formula of terminal exopods of P_{1-4} is 3,4,4,4 and setal formula of these same segments is 5,5,5,5), in the form of P_5 in that of the seminal receptacles, and in number of segments in the first antenna; but *C. capillatus* is strikingly different in the form of the furcal rami. The furcal ramus of *C. capillatus* is long and slender (4.5 to 5 times longer than broad) while that of *C. venustus* is short and broad (usually about 3 times longer than broad); the outer lateral seta of *C. capillatus* is inserted at about the middle of the furcal ramus, while that of *C. venustus* is inserted at about the beginning of the distal third of the furcal ramus; and finally, the furcal ramus of *C. capillatus* lacks hairs on its inner margin, while these hairs are present in *C. venustus*. There are other minor structural differences between these two species. *C. venustus* is more stubby in gneral body form and in the swimming feet, and has scale-like cuticular ridges that *C. capillatus* lacks (Gurney, 1933).

As mentioned above, Konganevik (Camden Bay), Arctic Alaska is the only locality where *capillatus* has been found in North America.



of C. *b. thomasi* from Durham City Reservoir, Durham County, N. C. 100. Endopod 3 of P4 of C. *b. thomasi* from Langford Lake, V. I., British Columbia. 101. Endopod 3 of P4 of C. *bicuspidatus* from Basins of Laboratoire d'Evolution, University of Paris, France. 102. P5 of C. *b. thomasi*. 103. Seminal receptacle of C. *b. thomasi*. (99-103 drawn to same scale).

CYCLOPS BICUSPIDATUS Claus, 1857

(Figs. 93, 98, and 101)

Cyclops bicuspidatus Claus 1857—Arch. Naturg. **23**(1):209, Pl. XI, Figs. 6 & 7.
Cyclops pulchellus Sars 1863.
Cyclops lubbocki Brady 1868.
Cyclops odessanus Schmankewitsch 1875.
Cyclops insignis (not Claus) Brady 1878.
Cyclops helgolandicus Rehberg 1880.
Cyclops entzii Daday 1882.
Cyclops roseus Daday 1882.
Cyclops bicuspidatus Schmeil 1892.
Cyclops bicuspidatus Kiefer 1929.
Cyclops bicuspidatus Gurney 1933.

Two European specimens were measured and examined—one collected by Dr. R. E. Coker from basins of the Laboratoire d'Evolution, University of Paris, France (11/17/23) and the other given Dr. Coker by J. Roy from Marais, France (12/8/36). There is a question as to whether or not the typical European form of *C. bicuspidatus* has been found in North America. E. B. Forbes (1897) found only a single specimen (at Woods Hole, Mass.) which conformed, he thought, with Schmeil's description of the European *C. bicuspidatus*. Forbes says, that *C. bicuspidatus* differs from the common American form, *C. b. thomasi*, mainly in the shape of the fifth foot. The differences which I have found between *C. bicuspidatus* and *C. b. thomasi* are given later.

The length of the female *C. bicuspidatus* is: 1.3 to 2.0 mm., according to Schmeil (1892); 1.3 mm. according to Sars (1918); 1.4 mm., according to Kiefer (1929); and 0.95 to 1.57 mm., according to Gurney (1933). The French specimens, mentioned above, measure 0.983 and 1.05 mm. *C. bicuspidatus* is rather robust in appearance. The posterior margins of the abdominal segments (except the last which has its posterior margin armed with small spines) are serrated. The posterior-lateral angles of the dorsa of the 5th and rarely the 4th thoracic segments (see Fig. 93) are very slightly outwardly produced. These lateral extensions are not nearly as prominent as in *C. b. thomasi*. Furcal rami are slender, being about six times longer than broad according to Gurney (1933), or with a quotient of length into width of about 0.16. The French copepods had furcal rami with the quotient of length into width 0.138 and 0.155. The small lateral seta is inserted at a point 60% to 68% 63% and 64%, respectively, in the French copepods) of the distance from base to distal end of the furcal ramus, according to Gurney (1933).

PLATE 8. Figs. 81-103. *Cyclops bicuspidatus thomasi* S. A. Forbes and *Cyclops bicuspidatus* Claus. 91. *C. b. thomasi*—adult female from Durham City reservoir, Durham County, N. C. 92. *C. b. thomasi*—left side of dorsum of 3rd, 4th, and 5th thoracic segments. 93. *C. bicuspidatus*—left side of dorsum of 2nd, 3rd and 4th thoracic segments. 94. *C. b. thomasi*—12th, 13th, 14th and 15th segments of first antenna. 95. *C. b. thomasi*—outer lateral view of furcal ramus. 96. Furcal rami of *C. b. thomasi* from Durham County, N. C. (1/11/26). 97. Furcal ramus of *C. b. thomasi* from Lookout Shoals Lake, Catawba Co., N. C. (4/5/35). (92-95 and 97 drawn to same scale). 98. Furcal ramus of *C. bicuspidatus* from Marais, France. Same scale as 96. 99. Endopod 3 of P4

Inner margins of the furcal rami are not hairy. Relative terminal, furcal setal lengths, innermost to outermost, are 1.10: 10.4: 5.5: 1 and 1.22: 11.0: 6.8: 1 in the French copepods. The innermost seta, which is much shorter than the furcal ramus, is not much longer than the outermost seta, while the inner long seta is almost twice as long as the outer long seta (see Fig. 98). The first antenna is of 17 segments and extends about to the posterior margin of the 1st body segment. The aesthete at the distal end of the 12th antennal segment extends beyond the 14th segment.

P_{1-4} have inner and outer rami of 3 segments. The spine formula of the third segment of the exopods of P_{1-4} is 2,3,3,3 (see Table 1, Type A, for complete armature of P_{1-4}). The third segment of the endopod of P_4 in the French *C. bicuspidatus* (see Fig. 101) is somewhat more stubby than that of *C. b. thomasi*—the quotient of length into width of the former being 0.270 to 0.280, and of the latter being 0.238 to 0.25. Gurney (1933) gives the length of this segment as for *C. bicuspidatus* s. str., two to three times the width (stubbier than in our French specimens), and for *C. b. thomasi,* more than three times the width (as in our American specimens). Quotient of length of segment into length of longest terminal spine is 0.675 and 0.81 in the French copepods. Gurney (1933) says that the longer of the two terminal spines is usually shorter than the segment, but may be longer. The outer terminal spine is about 1.44 times longer than the inner in the French copepods. The setae of segment 3 of P_4 do not extend to the ends of the terminal spines.

P_5 of *C. biscuspidatus* differs from that of nearly all other species in that the inner spine of segment 2 is almost apical and very long (see Fig. 102).

The seminal receptacle is of very distinctive shape (see Fig. 103), with a convex anterior margin. This structure in my collections of both *C. bicuspidatus* and *C. b. thomasi* agrees with descriptions and drawings for *C. bicuspidatus* given by Schmeil, Gurney, Kiefer, and Sars.

This species in the strict sense is not present in America unless E. B. Forbes' record of a specimen from Woods Hole, Mass., is accepted.

CYCLOPS BICUSPIDATUS THOMASI [9] S. A. Forbes, 1882
(Figs. 91-103, except 93, 98, & 101)

Cyclops thomasi S. A. Forbes 1882, Amer. Nat. **16**:649, figs.
Cyclops pectinatus Herrick 1883.
Cyclops bicuspidatus (part) Schmeil 1892.
Cyclops minnilus S. A. Forbes 1893.
Cyclops serratus (not Pratz) S. A. Forbes 1893.
Cyclops forbesi Herrick 1895.
Cyclops bicuspidatus E. B. Forbes 1897.
Cyclops thomasi Sars 1918.
Cyclops thomasi Kiefer 1929.
Cyclops bicuspidatus thomasi Gurney 1933.
Cyclops bicuspidatus thomasi Coker and McKee 1940.

9 Kiefer's *C. Diacyclops haueri,* was described as a new species in 1931 both in Zoologische Jahrbücher Abt. Syst. **61**:502 and Zoologischer Anzeiger **94**:220. It is recorded as differing from *bicuspidatus* and *thomasi* only in that the outer terminal spine of the endopod of P4 is shorter than the inner (Incorrectly stated as longer in the Zoologische Jahrbücher).

CYCLOPS BICUSPIDATUS NAVUS Herrick, 1882

(Figs. 161-167, p. 86)

Cyclops navus Herrick 1882, Rep. Geol. Sur. Minnesota, **10**:229.
Cyclops bicuspidatus (part.) Schmeil 1892.
Cyclops navus Marsh 1893.
Cyclops pulchellus var. *navus* Herrick 1895.
Cyclops bicuspidatus (part.) E. B. Forbes 1897.
Cyclops bicuspidatus var. *navus* Marsh 1910.

Specimens of *C. bicuspidatus thomasi* Forbes were secured from Durham Reservoir, Durham County, North Carolina (1/11/26); from Lookout Shoals Lake, Catawba County, N. C. (4/5/35); and from Langford Lake, Vancouver Island, British Columbia.

Body length of the female specimens varies from 0.950 to 1.168 mm., and the general body appearance is somewhat robust, though its abdominal segments and furcal rami are slender (see Fig. 91). Kiefer (1929) gives the length of the female *thomasi* as 0.9 mm., and Gurney (1933) gives the length as about 1.0 mm. The posterior borders of the abdominal segments (except the last segment, which has its posterior border armed with small spines) are serrated though not coarsely. In the North Carolina copepods, both the 4th and the 5th thoracic segments had outwardly-produced, posterior-lateral angles of the dorsa, which agrees with the observations of Forbes (1897), Coker and McKee (1940), and others, although Gurney (1933) mentions only a papilliform process on either side of the 5th thoracic segment in *C. b. thomasi*. Evidently Gurney's British *C. b. thomasi* specimens differ slightly from those commonly found in North America. Forbes (1897) mentions that in the far-western U. S. specimens, all the thoracic segments have laterally produced, postero-lateral angles of the dorsa. The furcal rami are usually long and slender, the quotient of length into width being 0.138 to 0.200. Specimens from Lookout Shoals Lake had relatively slimmer furcal rami than did those of Durham Reservoir, but the former were collected in April, and the latter in January. Seasonal changes, food, and other environmental conditions might, of course, account for differences. The small lateral seta is situated just beyond the middle of the furcal ramus or at a point 56% to 58% (60% to 68%, according to Gurney, 1933) of the distance from base to distal end of the ramus. Just about ¼ the distance from the proximal end or base of the furcal ramus, there is, on the outer side, a vertical comb of small spines. This comb was well described and drawn by Forbes in 1897. These two characters (small comb on furcal ramus and lateral seta inserted at about the middle of the furcal ramus) immediately enable one to distinguish forms of *C. bicuspidatus* (excluding *C. bicuspidatus navus*, described later in this account) from most other cyclopoid copepods. The inner margin of the furcal ramus is not hairy. The relative lengths of the terminal furcal setae, innermost to outermost, give such ratios as 1.18: 10.18: 5.8: 1 and 1.23: 13: 6.3: 1. The innermost terminal seta is much shorter than the furcal ramus.

The 1st antenna is generally like that of the European *C. bicuspidatus*, but usually extends slightly beyond the posterior border of the first thoracic seg-

ment, although sometimes it extends further. All the North American specimens of *C. bicuspidatus* examined had 17 segmented 1st antennae. The aesthete as the distal end of segment 12 is rather large, and extends beyond the distal end of segment 14 (see Fig. 94).

The rami of P_{1-4} have 3 segments each, and the spine formula of segment 3 of exopods of P_{1-4} is 2,3,3,3. The complete armature of the swimming feet is of Type A, Table 1. The terminal segment of the P_4 endopod is slender—the quotient of length into width is about 0.238 to 0.33 (see Fig. 99). Quotient of length of segment into length of longest terminal spine is 0.744 to 1.20. The length of the outer terminal spine is 1.73 to at least 2.28 times that of the inner spine. One of the characteristics of *C. b. thomasi* (as given by Gurney, 1933 and figured by Forbes, 1893) that aids in distinguishing it from *C. bicuspidatus*, is that the outer seta of P_4 endopod 3 extends beyond the outer terminal spine. Such is not the case in the North Carolina specimens (see Fig. 99), but individuals of *C. b. thomasi* from Langford Lake, Vancouver Island, British Columbia, have the setae of endopod 3 of P_4 extending beyond the terminal spines (see Fig. 100).

P_5 is like that of the European *C. bicuspidatus*, as is the seminal receptacle (see Figs. 102 & 103 and the description above). Forbes (1897) says that P_5 of *thomasi* differs in shape from that of the European *bicuspidatus*, but I have been unable to find in available collections any difference in respect to P_5.

Sars (1918) states that specimens of *thomasi*, sent by Forbes, are distinct from *C. bicuspidatus*, and that, consequently, *C. thomasi* should be considered a separate species. According to descriptions and from examinations of specimens, the differences between *C. bicuspidatus* and *C. b. thomasi* appear very slight. *C. b. thomasi* generally has longer first antennae; has the outwardly-produced, postero-lateral angles of the dorsa of the last 2 thoracic segments more pronounced; has the terminal segment of the endopod of P_4 more slender; and has the outer terminal spine of this segment nearer twice as long as the inner spine.

A less common variety of *C. bicuspidatus* than *thomasi* and known as *C. bicuspidatus navus* Herrick has been found in certain regions of North America. It was described by Herrick in 1882 as a new species closely related to *C. bicuspidatus*. In 1893, Marsh considered *navus* as a possible variety of *C. pulchellus* (at that date, Marsh preferred the name *pulchellus* to that of *bicuspidatus*), and in 1910, Marsh definitely recognized *navus* as a variety of *C. bicuspidatus*. Forbes (1897) said that there were specimens in the Illinois River which completely bridge the gap between *C. bicuspidatus* and Herrick's *C. navus* and that he could see no reason for considering *navus* a good variety.

Through the kindness of Mr. John M. Geary of the Health Department at Chapel Hill, N. C., recently some copepods were obtained which proved to be specimens of *C. bicuspidatus navus*. These copepods were taken from a 42 foot well on the farm of Bernice Wilkie, 12 miles east of Pittsboro, N. C. This well was dug in 1917 through 6 or 8 feet of surface sand loam and the remaining thick clay. Its top portion is reinforced with brick and cement and

is enclosed in a screened porch, so that no light reaches the water which is 7 or 8 feet deep. This unusual type of habitat unfortunately has been little investigated by American students of copepods.

Body length of female copepods from this well varies from 0.90 to 1.15 mm. The form generally appears more robust than *C. bicuspidatus* and lateral protrusions of the dorsa of the 4th thoracic segment seem to be lacking (compare Fig. 162 with Figs. 92 & 93). Herrick (1882) says that the "operculum vulvae are of peculiar shape" and I find this true of these specimens (see Fig. 163). The furcal rami are generally 3 times longer than the last abdominal segment (Marsh, 1882) or about 4 times as long as broad (FW/FL = 0.254 to 0.30), thus being considerably stubbier than in *C. bicuspidatus* (see Figs. 96-98 & 163). The small lateral seta is attached at a point 65 to 71% of the distance from base to apex of the furcal ramus. Thus it is more distally placed than that of *C. bicuspidatus*. Relative lengths of the terminal furcal setae, innermost to outermost, give such ratios as 1.57: 8: 4.87: 1 and 1.84: 8.3: 5.26: 1. The innermost terminal seta is slightly shorter than the furcal ramus.

The first antenna, like that of *C. bicuspidatus*, extends to the posterior border of the first thoracic segment or to the middle of the second. Armature of P_{1-4} is as in *C. bicuspidatus*. Quotient of length into width of the terminal segment of the endopod of P_4 is 0.330 to 0.375. This it is more stubby than that of either *C. bicuspidatus* or *C. bicuspidatus thomasi* (see Figs. 99-101 & 164, 165). Quotient of length of segment into length of the longer of the two terminal spines is 0.937 to 0.01. The outer terminal spine is about 1.40 to 1.43 times longer than the inner spine and in this respect it resembles *C. bicuspidatus* more closely than *C. bicuspidatus thomasi*. The setae of this segment do not extend to the end of the longer terminal spine.

As Marsh (1893) mentioned, P_5 differs from that of *C. bicuspidatus* in having the spine of the second segment more nearly the length of the apical seta (see Figs. 102, 166, 167). A tiny spinule is sometimes noticeable at the base of the spine, as in the case of *C. bicuspidatus*.

The seminal receptacle is like that of *C. bicuspidatus*.

Experiments in rearing *C. bicuspidatus navus* under various environmental conditions and mating attempts with *C. bicuspidatus thomasi* will have to be completed before the taxonomic status of *navus* is determined. Certainly the greatest difference between *navus* and *bicuspidatus* is found in the furcal ramus. Whereas *navus* has been reported from several northern states, particularly Minnesota, Wisconsin, and Illinois, the above North Carolina record seems to be the first for the southern part of the United States.

It is questionable whether *C. bicuspidatus minnilus* Forbes and *C. bicuspidatus forbesi* Herrick should be separated from *C. bicuspidatus thomasi* as different subspecies. Forbes' original description (1893) of *minnilus* gives no important difference between this animal and *thomasi*. His description of the armature of the swimming feet of these specimens were not always accurate and in several instances he called a seta a spine or vice versa. In his 1893 redescription of *thomasi*, he described the three mesial setae of endopod 3 of

P_3 as "spines," but correctly drew them as setae. He placed too much emphasis on whether certain spines of the swimming feet are considered lateral or apical; for example, the more distal of the two spines of exopod of P_1 was described as apical in *minnilus* and lateral in *thomasi*, but it is really lateral, though almost intermediate between the two positions, in both *minnilus* and *thomasi*. E. B. Forbes (1897) did not even consider *minnilus* a good variety, since it differs from *C. bicuspidatus (C. bicuspidatus thomasi)* only in certain proportions of the body.

C. bicuspidatus forbesi Herrick was first described by S. Forbes (1893) as a new species, *C. serratus*. Since that name was preoccupied, Herrick (1895) substituted the name *C. forbesi*. It is said to be the most elongate of the American representatives of the species and has very prominent posterolateral extensions of the dorsa of the thoracic segments. According to Forbes' description, the armature of its swimming feet is similar to that of *minnilus*. E. B. Forbes (1897) did not consider *forbesi* a good variety of *C. bicuspidatus (C. b. thomasi)*, but says the vertical comb of spines of its furcal rami is but poorly developed. Both *minnilus* and *forbesi* were described from specimens collected in Wyoming.

No individuals of *C. bicuspidatus lubbocki* having 14-segmented first antennae (segment 8 not having divided to give rise to segments 8, 9, 10, 11) have been collected in North America, according to available literature. Byrnes' (1909) *bicuspidatus* specimens with 13-segmented first antennae might be considered specimens of *lubbocki* by some writers. In her description of *bicuspidatus* she says, "collections have usually been made in this locality in the spring, when it is characteristic of the form to become sexually mature while the antennae contain but thirteen segments, although ultimately the antennae acquire seventeen segments." Even though her fig. 5, Plate X, shows one of these specimens whose abdominal segments seem to indicate that it is sexually mature, there is a strong probability that her copepods were immature. She fails to figure their swimming feet, whose segmentation might indicate whether they are mature or not. and there is no substantiated record of changes in the number of antennal segments of a sexually mature copepod.

The opinions of some American and European authors have differed in the classification of *C. bicuspidatus* and some of its subspecies. *C. bicuspidatus* with its varieties (subspecies?, forms?) *lubbocki, thomasi, navus*, and others, proves to be a very variable species, which should lend itself well to experimentation. It is structurally more like *C. vernalis* than *C viridis*, as can be seen from the descriptions and drawings of these copepods.

Various forms and subspecies of *C. bicuspidatus* are very widely distributed over North America, being found as far north as Saskatchewan. *C. bicuspidatus thomasi*, the commonest subspecies, is abundant in the Great Lakes and lakes of the northern states, yet it is common in certain bodies of water in North Carolina (see above). No definite distribution for *C. bicuspidatus navus* has been given by any author. Forbes (1897) says the only American specimen of *C. bicuspidatus* Claus as described by Schmeil that he has seen was from Woods Hole, Massachusetts.

CYCLOPS BISETOSUS Rehberg, 1863
(Figs. 104-109)

Cyclops bicuspidatus (not Claus) Sars 1863.
Cyclops bisetosus Rehberg 1880, Abh. Nat. Ver. Bremen **6**:543.
Cyclops bisetosus Schmeil 1892.
Cyclops bisetosus Lilljeborg 1901.
Cyclops bisetosus Sars. 1918.
Cyclops bisetosus Kiefer 1929.
Cyclops bisetosus Gurney 1933.

Three individuals of this species were studied in the preparation of this account. These were collected from a pool in the road at Meudon (near Paris, France) by Coker, on February 13, 1933. Gurney (1933) reported it in a collection from Edmonton, Canada; so that it may be expected to occur in other localities of North America.

The length of the female, according to Schmeil (1892) averages 1.3 mm. (the largest he observed measured 1.6 mm.). Sars (1918) gives the length of the female as 1.0 to 1.25 mm., while Kiefer (1929) gives it as 1.0 to 1.5 mm. and Gurney (1933) as 0.84 to 1.2 mm. The Meudon copepods have lengths of 1.045 mm, and 1.1 mm. According to Gurney (1933), the body is slightly flattened but this is not noticeable in the Meudon specimens. The posterior borders of the abdominal segments (except the last, which has its posterior border armed with tiny spines) are very slightly or not at all serrated. The lateral angles of the 4th thoracic segment are rounded and not produced. The 5th thoracic segment is slightly produced laterally. The furcal rami are slender, being 5 to 7 times as long as broad, according to Gurney (1933). The quotient of length into width of the furcal ramus varies from 0.149 to 0.155 in the Meudon copepods. The small outer lateral seta is inserted at a point 77% to 79% (77% to 83%, according to Gurney, 1933) of the distance from base to distal end of the furcal ramus. The inner margins of the furcal rami are not hairy. The relative terminal, furcal setal lengths, innermost to outermost, give ratios such as 0.74: 8.14: 4.44: 1 and 0.77: 8.23: 5.85: 1. The innermost terminal seta is thus slightly shorter than the outermost seta, and is much shorter than the furcal ramus (see Fig. 105).

The first antennae are of 17 segments and extend about to or just beyond the posterior margin of the first abdominal segment. The aesthete at the distal end of the 12th antennal segment, extends to the distal end of the 14th segment.

The swimming feet have the inner and outer rami of 3 segments. The spine formula of the terminal segments of the exopods of P_{1-4} is 2,3,3,3. Modified Type A, Table 1, gives the complete armature of P_{1-4}. It is notable that *bisetosus* like *crassicaudis* has only one seta on the inner side of endopod 2 of P_1. The third segment of the endopod of P_4 is very stubby (see Figs. 106 & 107), having a quotient of length into width of 0.583 to 0.625 in the Meudon specimens. Gurney (1933) says that this segment is generally about 1.5 times longer than wide (= a quotient of length into width of about 0.666). Quotient of length of endopod 3 of P_4 into length of longest terminal

spine varies from 0.96 to 1.12. The inner terminal spine is about 1.40 to 1.42 times longer than the outer terminal spine in the Meudon specimens. The setae of endopod 3 of P_4 usually reach beyond the ends of the terminal spines.

P_5 has the inner spine of the second segment slightly longer than the segment and almost apical (see Fig. 108).

The seminal receptacle is of curious shape and difficult to describe. Fig. 109 shows the seminal receptacle of one of the Meudon specimens. It agrees fairly well with the figures of Kiefer (1929) and Gurney (1933).

In 1863, Sars (as acknowledged by him, 1918), wrongly identified the present species as *C. bicuspidatus* Claus but in 1880, Rehberg correctly made it a new species—*C. bisetosus*. Since 1880 there seems to have been little or no confusion of this species with others of the group. It is rather closely related to *C. jeanneli* Chappuis and *C. crassicaudis* Sars. Comparisons of *C. bisetosus* with these two species are given at the ends of the descriptions of these two species (see pp. 59 and pp. 63).

Kiefer (1828, 1829) says that his *C. crassicaudoides* is closely related to *C. bisetosus*, but so far it has been reported only from New Zealand. Like *bisetosus*, its first antennae are of 17 segments, its furcal rami are about 6 times as long as broad, the relative lengths of its terminal furcal setae are about 0.82: 8.7: 5.5: 1 (by our measurement of Kiefer's figure), its anal operculum extends far back, and its endopod 3 of P_4 is stubby with the inner terminal spine longer than the outer one and with the setae extending beyond the ends of these terminal spines; but it has the genital segment as large as with *C. crassicaudis* and a much more simple seminal receptacle. The seminal receptacle of *C. crassicaudoides* is figured (see Kiefer 1929) as having an anterior portion with a convex anterior margin and an equal-sized posterior portion with a median indentation in its posterior margin. The seminal receptacle of *C. bisetosus* is a complicated structure (see Fig. 109). For a comparison of *C. bisetosus* with *C. nearcticus* Kiefer see p. 58.

As mentioned above, *C. bisetosus* has been collected at Edmonton, Canada, but from nowhere else in North America as yet.

CYCLOPS NEARCTICUS Kiefer, 1934

(Figs. 110 and 111)

Cyclops nearcticus Kiefer 1934, Zool. Anzeiger **107**:270.

Kiefer described this species from a single female sent to him by E. G. Hutchinson in 1931. This specimen was collected from "Guilder Pond, Berkshires," Massachusetts. The following description is taken from Kiefer's description and figures.

Length of the female is 0.8 mm. In appearance, it resembles *Cyclops languidus* Sars. Furcal rami are almost parallel (see Fig. 110) and are 4 times as long as broad (92 : 23μ). Kiefer's figure shows the outer lateral furcal seta at a point about ¾ of the distance from base to apex of the ramus. The innermost terminal furcal seta is shorter or barely longer than outermost.

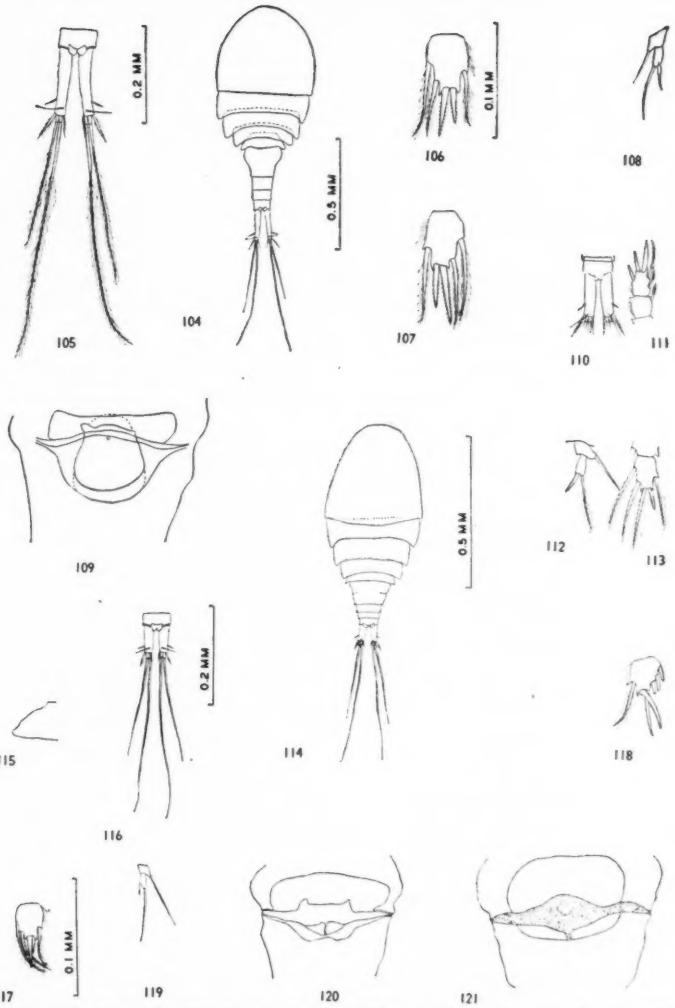


PLATE 9. Figs. 104-121. *Cyclops bisetosus* Rehberg, from Meudon, France. 104. Adult female, slightly flattened by cover-slip. 105. Last abdominal segment and furcal rami. 106 & 107. Endopod 3 of P4. 108. P5. 109. Seminal receptacle. (106-109 drawn to same scale.) *Cyclops nearcticus* Kiefer. (After Kiefer, 1934). 110. Furcal rami and last abdominal segment. 111. Endopod 2 and 3 of P4. *Cyclops jeanneli* Chappuis. (After Chappuis, 1929). 112. P5. 113. Endopod 3 of P4. *Cyclops crassicaudis brachycercus* Kiefer, from Chapel Hill, N. C. 114. Adult female. 115. Sharply produced angle of dorsum of 5th thoracic segment. 116. Furcal rami and last abdominal segment. 117. Endopod 3 of P4 of female. 118. Endopod 3 of P3 of male. 119. P5. 120 & 121. Variation in form of the seminal receptacle. (115 and 117-121 drawn to same scale.)

First antennae are of 17 segments and extend to the posterior edge of the cephalothorax. Each of the rami of P_{1-4} is 3-segmented. Armature of all the swimming feet is not given. Terminal segment of the inner ramus of P_4 (see Fig. 111) is 1.52 times as long as broad (35 : 23μ). Of the two terminal spines of this segment, the inner is almost twice as long as the outer (47 : 33μ). A short, firm spine instead of a seta is found on the outer side of the segment. P_5 resembles that of *C. bicuspidatus* Claus. Kiefer could not identify the seminal receptacle of this one specimen.

Nearcticus seems to resemble more nearly *C. bisetosus* than any other North American copepod, but it differs from that species in having a spine instead of a seta on the outer side of endopod 3 of P_4 and stubbier furcal rami (4 instead of 5 to 7 times as long as road). Other differences may be found when fuller descriptions and more specimens of *nearcticus* are available. As stated above, the only specimen of the species was taken in Massachusetts in 1931.

CYCLOPS JEANNELI Chappuis, 1929

(Figs. 112 and 113)

Cyclops jeanneli Chappuis 1929—Bull. Soc. Sci. Cluj. (Roumanie) **4**(2):51-57.
Cyclops jeanneli Kiefer 1929.

The species was described from specimens taken from Morengo Cave, Indiana. Since no specimens are available, the following description is taken from the original description and figures by Chappuis.

The female body length is 0.9 mm., without the furcal setae and 1.35 mm. with these setae. Greatest width is 0.3 mm. the genital segment is large, and the posterior margins of the abdominal segments are very slightly toothed on the dorsal side. The anal operculum is slightly pronounced. Chappuis did not mention there being any outwardly-produced, postero-lateral angles of the dorsa of the 4th and 5th thoracic segments. Furcal rami are relatively short, 3.5 times longer than broad, or with a quotient of length into width 0.285. The lateral seta is inserted at the lower third of the furcal ramus. The description does not state whether the inner margins of the furcal rami are hairy or not; presumably they are not since Chappuis generally mentions these hairs when present. Relative lengths of the terminal setae of the furcal ramus, innermost to outermost, are about 2: 12.5: 7.5: 1.

First antennae are of 17 segments and extend a little beyond the first segment of the body. The aesthete at the distal end of the 12th antennal segment extends to the first half of segment 15.

Rami of P_{1-4} are trisegmented. The spine formula of the terminal segments of exopods of the swimming feet is not given. Terminal segment of endopod of P_4 is short, 1.5 times longer than broad, or with a quotient of length into width 0.666, as mentioned in the text. Measurement of the figure of this segment by the method given on p. 13 results in a quotient of length into width of 0.64. A seta replaces the inner terminal spine of this segment

according to Chappuis (see Fig. 113). This structural modification makes this copepod distinct from all others of the genus, and it is hardly possible that Chappuis has mistaken a very long inner spine (commonly found in the subgenus in which this species is placed by Chappuis and Kiefer, 1929) for a seta. By measurement of Chappuis' figure, this long, inner terminal seta is 2.07 times longer than the segment and 2.9 times longer than the small outer spine. The inner, lateral setae and the outer lateral seta extend far beyond the distal end of the small, outer spine, but do not quite reach the end of the long terminal seta.

P_5 is much like that of *C. bisetosus,* having a rather narrow basal segment with an outer seta and a more narrow distal segment, with an apical seta and an inner spine that is slightly longer than the segment and almost apical (see Fig. 112).

Chappuis says that the seminal receptacle was not well preserved in those specimens, but that it seemed to resemble that of *C. crassicaudis.*

The male of *C. jeanneli* has the same swimming feet and P_5 as the female, and its genital segment is very broad.

Chappuis suggests that *C. jeanneli* shows resemblance to *C. bisetosus* and *C. crassicaudoides,* on one hand, and to *C. crassicaudis,* on the other hand.

C. jeanneli resembles *C. crassicaudis* in size, in general appearance, and in stubbiness of furcal rami. The relative lengths of the furcal setae agree in the two species, except in the case of the innermost seta, which is twice the length of the outer in *C. jeanneli,* but shorter than the outer in *C. crassicaudis. C. jeanneli* has 17 segments to each first antenna, while *C. crassicaudis* has but 12. Endopod 3 of P_4 is not as stubby in *C. jeanneli* as in *C. crassicaudis* and it has a long inner terminal seta instead of the long inner terminal spine of *C. crassicaudis.* P_5 is much like that of *C. crassicaudis,* but its inner spine of segment 2 is often relatively longer.

C. jeanneli resembles *C. bisetosus* in number of segments of first antennae (not important), in proportions of endopod 3 of P_4, and in proportions of P_5, but it has more stubby furcal rami, more proximally placed outer lateral seta of furcal rami, very different relative terminal setal lengths, and a long inner terminal seta of endopod 3 of P_4 instead of a long inner terminal spine.

C. crassicaudoides Kiefer (1928, 1929) has been reported only from New Zealand. As in *C. jeanneli,* its first antennae are of 17 segments, its anal operculum extends far back, and its genital segment is large; but it has a long inner terminal spine on endopod 3 of P_4 instead of a long inner terminal seta as found in *C. jeanneli,* its furcal rami are about 6 times instead of about 3.5 times as long as broad, and the relative lengths of its terminal furcal setae are quite different from those of *jeanneli.*

From the available information on *C. jeanneli,* we conclude that it is more closely related to *C. crassicaudis* than to *C. crassicaudoides* and *C. bisetosus,* but that it shows resemblances to all three. The replacement of the long,

inner, terminal spine by a long seta may be due to a mutation or to a non-inheritable abnormality in the specimen or specimens (the number was not given) described by Chappuis.

The specimen (or specimens) of *C. jeanneli* from Morengo Cave in Indiana give us the only record of the species in the world.

CYCLOPS CRASSICAUDIS Sars, 1863

Cyclops crassicaudis Sars 1863, Forh. Vid. Selsk. Christiana **1862**:249.
Cyclops brucei Scott 1899.
Cyclops crassicaudis Lilljeborg 1901.
Cyclops crassicaudis Kiefer 1929.
Cyclops crassicaudis cretensis Kiefer 1929.
Cyclops crassicaudis taipenhensis Harada 1931.
Cyclops crassicaudis Gurney 1933.

CYCLOPS CRASSICAUDIS BRACHYCERCUS Kiefer, 1929
(Figs. 114-121)

Cyclops crassicaudis brachycercus Kiefer 1929, Zool. Anzeig. **72**:263, figs.
Cyclops bissextilis Willey 1929.
Cyclops crassicaudis Coker 1938.

About 26 female and 5 male specimens collected from a rut in Fire Lane Road, Chapel Hill, N. C., were examined. The species seems to be rather rare in America. It was collected by L. L. Hill, at Chapel Hill, N. C., in 1927, (Coker 1938) and has been taken from the same station several times in different years, but the species has remained very local in its distribution about Chapel Hill. In the spring of 1941, dozens of them were collected in the above mentioned road rut, but nearby pools yielded none. Kiefer (1927) reported it from New York and Willey (1929) found it in Canada.

Body lengths (exclusive of the furcal setae) of adult females are 0.90 to 1.10 mm. according to Sars; 0.78 to 0.90 for the European *C. crassicaudis* and 0.72 to 0.86 mm. for *C. crassicaudis brachycercus* according to Kiefer (1927, 1929); and 0.93 to 1 mm., according to Gurney (1933). Chapel Hill specimens are small, being only 0.54 to about 0.77 mm. in length. The genital segment is noticeably broad. Posterior borders of abdominal segments (except the last, which has its posterior border armed with small spines) are serrated. Fifth thoracic segment with postero-lateral angles of the dorsa conspicuously outward-produced. The furcal rami are 4 to 5 times longer than wide in the European *crassicaudis*, according to Gurney (1933), and 3.2 to 3.4 times longer than wide in the American *C. crassicaudis brachycercus*, according to Kiefer (1927, 1929). Quotient of length into width of the furcal rami of the Chapel Hill specimens is about 0.28 to 0.32. The small lateral seta of the furcal ramus is attached at a point 72% to 73% of the distance from base to tip of ramus. Inner margins of furcal rami are not hairy. Relative lengths of terminal furcal setae, innermost to outermost, give ratios such as 0.66: 13.7: 7.2: 1 and 0.87: 11.3: 6.4: 1, the innermost terminal seta is always shorter than the outermost one, and the longest terminal seta is almost twice the length of the next longest terminal seta (see Fig. 116).

First antennae are of 12 segments, reaching about to the posterior margin of the first body segment. Aesthete at middle of the 9th segment, extends beyond distal margin of that segment. P_{1-4} with inner and outer rami of 3 segments. Spine formura of terminal segments of exopods of P_{1-4} is 2,3,3,3. Complete armature of the swimming feet is of modified Type A (see Table 1). This species as well as *C. bisetosus* has only one seta on the inner side of endopod 2 of P_1.

Terminal segment of endopod of P_4 is almost as broad as long (see Fig. 117), having the quotient of length into width 0.78 to 0.96. Quotient of length of longest terminal spine is 1.04 to 1.30. Inner terminal spine is 1.42 to 1.80 times longer than the outer. Inner setae (and sometimes the outer seta) of endopod 3 of P_4 extend beyond tips of terminal spines (see Fig. 117).

P_5 is like that of *C. bisetosus* with the inner spine of segment 2 rather long and almost apical (see Fig. 119).

The seminal receptacle has the anterior margin convex or slightly concave (see Figs. 120 & 121 and further description below).

One structural feature of the male *C. crassicaudis* is very noticeable. The outer terminal spine of endopod 3 of P_3 crosses an inner terminal spine (see Fig. 118) or an inner terminal seta. In all American specimens of *C. crassicaudis* examined, there is an inner terminal spine of endopod 3 of P_3 instead of the inner terminal seta of the typical European *C. crassicaudis*. Kiefer (1927, 1929), Gurney (1933), and Coker (1938) mention this difference between the American form (called *C. crassicaudis brachycercus* by Kiefer, 1929) and the typical European form. Such crossed spines or crossed seta and spine are found on males of several other species of copepods (see Figs. 50 & 65).

The description of the Chapel Hill specimens seems to place them in the subspecies *C. c. brachycercus* Kiefer. The typical European form (apparently not yet found in America) has the furcal rami more slender, is somewhat larger in size than brachycercus, has a somewhat stubbier endopod 3 of P_4, and has an inner terminal seta of endopod 3 of P_3 of the male instead of a spine, crossed in both cases by the outer terminal spine.

The female *C. crassicaudis* resembles the female *C. bisetosus* Rehberg in a number of ways: both have the innermost terminal furcal seta longer than the outermost one and the longest terminal furcal seta almost twice as long as the next longest furcal seta; both lack hairs on the inner margins of the furcal rami; both have only one seta on the inner side of endopod 2 of P_1; both have endopod 3 of P_4 very stubby and the inner terminal spine of this segment much longer than the outer spine and usually longer than the segment; P_5 of both are much alike; and finally the seminal receptacles seem to be somewhat alike in some specimens. Fig. 120 shows one type of seminal receptacle of *C. crassicaudis* with 2 horn-like projections from the anterior sperm-containing portion that is somewhat like the seminal receptacle figures of *C. bisetosus* drawn by Kiefer (1929) and Gurney (1933). Most seminal

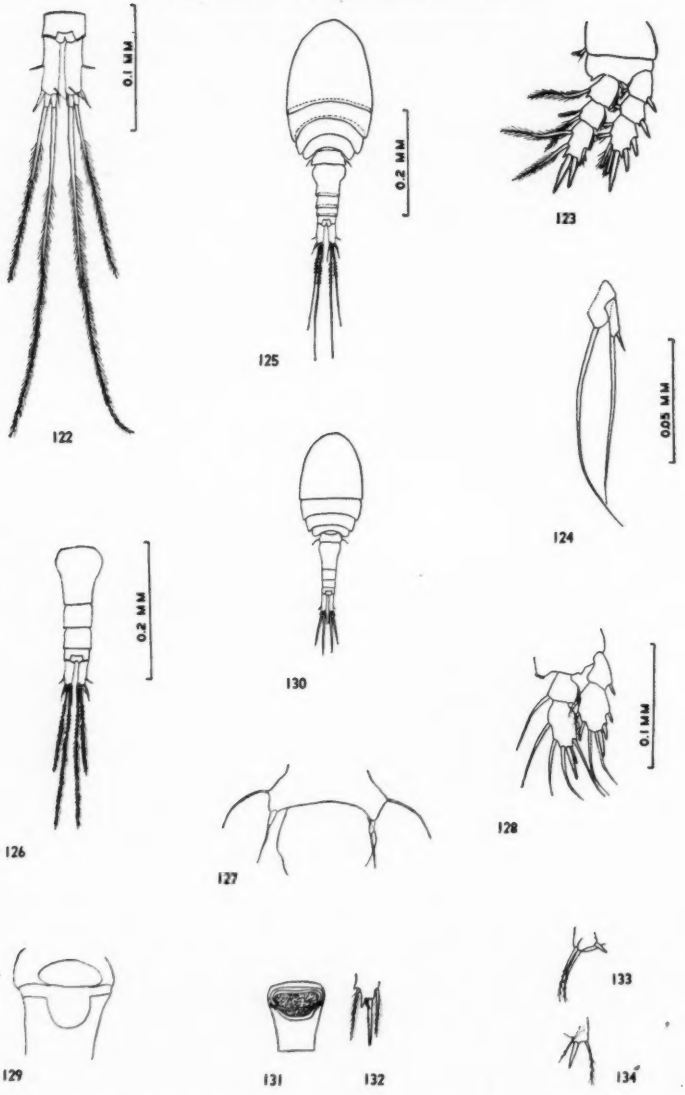


PLATE 10. Figs. 122-134. *Cyclops nanus* Sars, from White Lake, N. C. 122. Furcal rami and last abdominal segment. 123. P4. Same scale as 122. 124. P5. *Cyclops varicans rubellus* Lilljeborg, from Chapel Hill, N. C. 125. Adult female. 126. Furcal rami and

receptacles of *C. crassicaudis* are like that of Fig. 121, which is somewhat like Gurney's (1933) figure for *C. crassicaudis*.

C. crassicaudis differs from *C. bisetosus* in having: (1) the 1st antenna of 12 instead of 17 segments, (2) the fifth thoracic segment with the posterolateral angles sharply produced, (3) stubbier furcal rami,)4) the small lateral furcal seta nearer the middle of the ramus, (5) a seminal receptacle of different shape, and (6) the endopod 3 of P_3 in the male copepod with an outer terminal spine crossing an inner terminal spine or an inner terminal seta.

Another copepod with which *C. crassicaudis* might be confused is *C. crassicaudoides* Kiefer. The latter species has so far been found only in New Zealand. It is placed close to *C. bisetosus* and *C. crassicaudis* by Kiefer. According to Kiefer (1928, 1929), its genital segment is large as in *C. crassicaudis*, but it has furcal rami 6 times longer than broad and relative lengths of its terminal furcal setae about 0.82: 8.7: 5.5: 1, has the first antennae of 17 segments instead of 12, and has a seminal receptacle with an anterior portion with convex anterior margin and an equal-sized posterior portion with median indentation in its posterior margin.

As was mentioned at the beginning of this description, *C. crassicaudis*, represented by the subspecies *brachycercus*, is rare in North America, having been collected only in Orange County, North Carolina (and there repeatedly, in one narrowly restricted locality); in New York; and in Canada.

CYCLOPS NANUS Sars, 1863

(Figs. 122-124)

Cyclops nanus Sars 1863, Forh. Vid. Selsk. Christiana **1862**:251.
Cyclops languidus var. *nanus* Schmeil 1897.
Cyclops diaphanus (part.) Lilljeborg 1901.
Cyclops diaphanus var. *diaphanoides* Graeter 1903.
Cyclops incertus Wolf 1905.
Cyclops languidoides (not Lilljeborg) Klie 1913.
Cyclops diaphanus (part.) Sars 1918.
Cyclops languidus var. *intermedia* Kiefer 1923.
Cyclops nanus Kiefer 1929.
Cyclops nanus Gurney 1933.
Cyclops nanus Coker 1938.

Examination was made of two specimens collected by the class in Hydrobiology, University of N. C., from bottom material at White Lake, Bladen County, North Carolina, on October 17, 1937.

The species had been collected at only two localities in the Western Hemisphere—White Lake, Bladen County, N. C. (see Coker 1938 and 1938a) and Lake Talassee, Montgomery County, N. C. (McKee and Coker 1940). As

abdominal segments of female. 127. Ventral view of 5th thoracic segment and fifth feet. 128. P4. 129. Seminal receptacle. (127-129 drawn to same scale.) *Cyclops bicolor* Sars. (After Sars, 1918.) 130. Adult female. 131. Seminal receptacle. 132. Distal end of endopod 3 of P4. *Cyclops dimorphus* Kiefer (After Kiefer, 1934). 133. P5 of female. 134. P5 of male.

indicated by its specific name, this copepod is very small—the female being 0.70 to 0.90 mm. in length (exclusive of the furcal setae), according to Sars (1918), 0.66 to 0.90 mm. according to Kiefer (1929), and 0.7 to 0.72 mm. according to Gurney (1933). The White Lake specimens had been previously dissected, but Coker (1938a) found the length to be 0.45 mm. for the female and 0.4 mm. for the male. The posterior borders of the abdominal segments (except the last which has its posterior border armed with tiny spines) are very slightly, or not at all, serrated. The postero-lateral angles of the dorsum of the next to the last thoracic segment are not outwardly produced. The 5th thoracic segment is very slightly produced laterally. The furcal rami are about 5 times as long as wide, according to Gurney (1933), but those of the dwarfed White Lake specimens are somewhat more stubby, having a quotient of length into width of 0.240 to 0.268. The small lateral seta is inserted at a point 50% to 53% of the distance from base to tip of the furcal ramus. The inner margins of the furcal rami are not hairy. The relative lengths of the terminal furcal setae, innermost to outermost, give ratios such as 0.65: 10.5: 5.65: 1 and 0.65: 14.5: 7.95: 1. The innermost terminal seta is thus much shorter than the outermost one and much shorter than the furcal ramus (see Fig. 122).

The first antenna is of 11 segments and does not extend to the posterior margin of the first segment of the body. The aesthete is inserted at the middle of the 8th segment and extends beyond the middle of the 9th segment.

The first two pair of swimming feet are imperfectly developed. Both inner and outer rami of the 1st pair of swimming feet are of two segments, as are the inner rami of the second pair of swimming feet. The outer rami of the second pair of swimming feet and both inner and outer rami of the 3rd and 4th pair of swimming feet are of 3 segments. The spine formula of the terminal segments of the exopods of P_{1-4} is 3,3,3,3. The complete armature of P_{1-4} is of Type D (see Table 1). Proximal seta of inner side of endopod 2 of P_4 is less than ½ the length of the distal seta (see Fig. 123). The terminal segment of endopod of P_4 is more than twice as long as wide, according to Gurney (1933). Quotient of length into width of this segment is 0.448 to 0.553 in the White Lake specimens. Quotient of length of segment into length of longest terminal spine is about 1.17 to 1.20. The inner terminal spine is about 1.24 to 1.35 times longer than the outer. The basal segment of P_5 is either separated or not separated from the fifth thoracic segment. The second segment of P_5 is slender and has the inner spine rather long and almost apical (see Fig. 124).

The seminal receptacle consists of a large transversely oval anterior portion (which may have a slight median indentation of the anterior margin) and a very small posterior portion.

Three species of copepods that have not yet been found in America, but which might be confused with *C. nanus*, are:—*C. languidus* Sars, *C. languidoides* Lilljeborg (and its many subspecies), and *C. abyssicola* Lilljeborg. These three species and *C. nanus* Sars agree in segmentation and armature of

the legs, and in the shape of the seminal receptacle, and are of approximately the same size.

C. nanus Sars differs from *C. languidus* Sars in having only 11 segments in the first antenna as compared with 16 in the first antenna of *C. languidus*. Because of this difference in segmentation of the 1st antenna of the two species, the aesthete of *C. nanus* is inserted at the middle of the 8th segment, while that of *C. languidus* is inserted at the distal margin of the 11th segment. The small lateral furcal seta is inserted at about the middle of the furcal ramus in *C. nanus*, while it is inserted at a point about 66% to 73% of the distance from base to tip of furcal ramus in *C. languidus* (Gurney, 1933). Endopod 3 of P_4 is about 1.5 to 1.7 times longer than wide in *C. languidus* (Gurney, 1933), but 2 or more times as long as wide in *C. nanus*. The terminal spines of endopod 3 of P_4 are nearly equal in length, but with the inner a little longer than the outer, and much shorter than the segment in *C. languidus* (Gurney, 1933); while the inner terminal spine is much longer than the outer and longer than the segment in *C. nanus*. The fifth thoracic segment has the outer angle slightly upturned in *C. languidus* (Gurney, 1933), such is not the case in *C. nanus*.

Both *C. nanus* Sars and the very variable *C. languidoides* Lilljeborg have the first antennae of 11 segments. *C. nanus* differs from all 11 forms of *C. languidoides* (described by Kiefer, 1931) in having the small, lateral furcal seta inserted at about the middle of the furcal ramus, while this seta is inserted at the distal third of the furcal ramus in all forms of *C. languidoides* (Gurney, 1933). There are other differences between each form of *C. languidoides* and *C. nanus*, but since *C. languidoides* has not yet been found in America, these differences are not given here. For those interested, see Gurney's British Freshwater Copepoda 3:236, 1933.)

C. nanus differs from *C. abyssicola* Lilljeborg in having the first antennae of 11 segments, while *C. abyssicola* has the first antennae of 10 segments (Sars, 1918). The genital segment of *C. abyssicola* is relatively much larger than in *C. nanus* and the furcal rami are most stubby (Sars, 1918). The small lateral furcal seta is inserted in the distal third of the furcal ramus in *C. abyssicola* instead of in the middle as in *C. nanus*.

The comparisons may be expressed more briefly by a key.[10]

1. { First antennae of 16 segments—*C. languidus*
   { First antennae of less than 16 segments—2.

2. { First antennae of 10 segments—*C. abyssicola*
   { First antenna of 11 segments—3.

3. { Small lateral furcal seta inserted at about middle of ramus—*C. nanus*.
   { Small lateral furcal seta inserted in distal third of ramus—*C. languidoides*.

Since *nanus* has been collected only in Bladen and Montgomery Counties, North Carolina, it must at present be considered rare in North America.

10 This key is based mainly on segmentation of the first antennae and is useful insofar as the numbers of segments of the first antennae of these species do not vary.

CYCLOPS VARICANS Sars, 1863

Cyclops varicans Sars 1863, Forh. Vid. Selsk. Christiana. **1862**:252.
Cyclops orientalis Uljanin 1875.
Cyclops varicans Schmeil 1892.
Cyclops africanus Bourne 1893.
Cyclops varicans Lilljeborg 1901.
Cyclops varicans Sars 1918.
Cyclops ceibaensis Marsh 1919.
Cyclops subaequalis Kiefer 1927.
Cyclops varicans Kiefer 1929.
Cyclops varicans subaequalis Kiefer 1932.
Cyclops varicans Gurney 1933.

CYCLOPS VARICANS RUBELLUS Lilljeborg, 1901

(Figs. 125-129)

Cyclops bicolor (not Sars) Marsh 1893 and 1910.
Cyclops bicolor (not Sars) Herrick 1895.
Cyclops varicans E. B. Forbes 1897.
Cyclops rubellus Lilljeborg 1901, Svenska Ak. Handl. **35**:75.
Cyclops varicans var. *rubens* Wolf 1905.
Cyclops bicolor (not Sars) Byrnes 1909.
Cyclops varicans Spaeth 1914.
Cyclops varicans (part.) Sars 1918.
Cyclops davidi Chappuis 1922.
Cyclops rubellus Kiefer 1929.
Cyclops varicans rubellus Gurney 1933.
Cyclops bicolor (not Sars) Coker 1938.

Eight specimens of *C. varicans* were examined in the preparation of this description. Two of these were collected by Coker, at Sycamore Flats, Chapel Hill, North Carolina, in February, 1928, and the other six by myself from a marsh at the edge of University Lake, Chapel Hill, N. C., on April 4, 1941. It is rather abundant about Chapel Hill.

Herrick (1895) found the species only once in America, but Forbes (1897) said it was a fairly common species in North America. The former author gave figures and a description while the latter gave neither. Pearse (1904) reported it from Nantucket Island, Massachusetts, and Miss E. F. Byrnes' (1909) specimen of *"C. bicolor,"* with the 12-segmented 1st antennae, collected on Long Island, N. Y., is generally thought to be a specimen of *C. varicans* (see Spaeth, 1914). Spaeth (1914) found *varicans* in small numbers near Haverford, Pennsylvania, and Cambridge, Mass., and in Lake Winnepesaukee, New Hampshire. Wilson (1932) said it was abundant in ponds about Woods Hole, Mass. The form of *C. varicans* with 11-segmented first antennae has been identified as *C. bicolor* by several American authors. Marsh (1910) reported *"C. bicolor"* as not common, but widely distributed in America and said he had seen no specimens of *C. varicans* from North American waters, but Marsh's (1893 and 1910) and Herrick's (1895) descriptions and figures of *"C. bicolor"* show these copepods to be specimens of *C. varicans* instead of *C. bicolor* (see discussion at the end of this descriptIion). Willey has reported *C. varicans* from Canada, and Kiefer (1929a) has reported *C. rubellus* from New Haven, Connecticut. *C. varicans* is widely distributed abroad.

Body length of the female is 0.8 to 0.92 mm., according to Schmeil (1892); 0.70 to 0.90 mm., according to Sars (1918); 0.7 to 1.0 mm. for *C. varicans* and 0.6 to 0.9 mm. for *C. rubellus,* according to Kiefer (1929); and 0.6 to 0.9 mm. for both *C. varicans* and *C. v. rubellus* according to Gurney (1933). Spaeth's American specimens varied from 0.841 to 0.966 mm. and averaged about 0.867 mm. in length. Our Chapel Hill specimens vary from 0.51 to 0.65 mm. The body is rather stout, in general appearance (see Fig. 125). The 4th thoracic segment is not laterally produced, whereas the 5th thoracic segment is slightly produced laterally.

Posterior margins of the abdominal segments (except the last) are not serrated. The posterior margin of the last abdominal segment has only a few spines on the ventral side and none on the dorsal or lateral sides, as Gurney (1933) describes *C. varicans.* The Chapel Hill specimens agree with Gurney's (1933) description of *C. varicans rubellus* in having many very tiny spines along most of the posterior margin of the last abdominal segment.

The furcal rami are stubby, 3.5 to 4 times as long as broad for *C. varicans* and 2.5 to 3 times as long as broad for *C. rubellus,* according to Kiefer (1929); and 3 to 4 times as long as wide for *C. varicans* and 2.5 to 3 times as long as wide for *C. v. rubellus* according to Gurney (1933). Our Chapel Hill specimens had rami about 3 times as long as wide (to be more exact, the quotient of length into width of the furcal ramus is 0.30 to 0.35). The outer lateral furcal seta is attached at a point about 65% to 72% of the distance from base to apex of the ramus. The inner margins of the furcal rami lack hairs. Relative terminal furcal setal lengths, innermost to outermost, usually give ratios such as 1.19: 7.56: 4.7: 1 and 1.33: 8: 6: 1 in our specimens, but one individual had the relative lengths 1.47: 7.1: 4.8: 1. The inner of the two middle terminal furcal setae is rather slender, noticeably longer than the outer terminal seta (which is also slender), and at least as long as the furcal rami and all the abdominal segments combined (see Figs. 125 & 126). The innermost terminal furcal seta is usually shorter, but sometimes longer, than the ramus. Gurney (1933) says this seta is rarely longer than the ramus in *C. varicans* but usually as long as, or longer than, the ramus in *C. v. rubellus.* Spaeth (1914) says that the proximal portions of the two middle terminal furcal setae of his Pennsylvania specimens have a short row of thin spines on either side, instead of hairs. These spines end abruptly, and are replaced by the usual hairs in the distal portions of these setae. The Chapel Hill specimens agree with Spaeth's specimens in this respect (see Fig. 126), and Gurney's (1933) figure of these setae of *C. v. rubellus* show thin spines replacing the hairs in the proximal portions of the setae, although Gurney makes no mention of this.

First antennae are of 11 or 12 segments and do not extend to the posterior margin of the first segment of the body. As mentioned above, Marsh and others have identified specimens of *C. varicans* with 11-segmented antennae as *bicolor. C. varicans* is said to have 12-segmented 1st antennae, while the subspecies *C. v. rubellus* has either 11- or 12-segmented antennae, according to

Kiefer (1929) and Gurney (1933). Spaeth (1914) frequently found egg-bearing females with 11-segmented first antennae in late winter, but females with 12-segmented antennae were more common in April and May. An aesthete is present at the middle of the 9th antennal segment (8th segment in specimens with 11-segmented antennae), and extends about to the middle of the 10th antennal segment. This aesthete is usually difficult to see.

Swimming feet have inner and outer rami of 2 segments. Spine formula of the terminal segments of the exopods of P_{1-4} is 3,4,4,3 and the setal formula is 5,5,5,5. Type F. Table 1, gives the complete armature of P_{1-4}. Endopod of P_4 is stubby, usually $2\frac{1}{2}$ times as long as wide in *C. varicans* and hardly more than 2 timse as long as wide in *C. v. rubellus,* according to Gurney (1933). Quotient of length into width of endopod 2 of P_4 of the Chapel Hill specimens is about 0.42 to 0.52 (= a little less than 2.5 to a little less than 2 times as long as wide). In *C. varicans* the inner terminal spine of endopod 2 of P_4 is much longer than the outer spine and about as long, or slightly over half as long, as the segment in *C. varicans,* while in *C. v. rubellus,* it is not much longer than the outer spine and about half as long as the segment, according to Gurney (1933). The inner terminal spine in the Chapel Hill specimens is 1.75 to 2.26 times as long as the outer spine, and 0.74 to 0.816 times as long as the segment (see Fig. 128), agreeing with Gurney's description of *C. varicans,* but not that of *C. varicans rubellus.* The setae of endopod 2 of P_4 usually extend beyond the end of the inner terminal spine.

P_5 consists of only one distinct segment; the part that would generally constitute a basal segment is not separated from the last thoracic segment, but still bears an outer seta. The distinct segment is slender and cylindrical, with a seta at its apex, and with or without a tiny spine at the middle of the inner side. Gurney (1933) says this tiny inner spine of the distinct segment of P_5 is absent in *C. v. rubellus,* and that he is not sure whether it is always present in *C. varicans.* I was unable to see this spine in our specimens (see Fig. 127).

The seminal receptacle shows some diversity of form. The anterior portion is transversely oval, and the posterior protrudes like a bag (see Fig. 129). In my collection, posterior and anterior portions are about equal in size.

In summarizing the differences between *C. varicans* Sars and *C. varicans rubellus* Lilljeborg, *rubellus* has: (1) more and smaller spines on the posterior margin of the last abdominal segment; (2) shorter furcal rami; (3) innermost terminal furcal seta usually longer than the ramus (in *varicans* it is usually shorter than the ramus); (4) a more stubby endopod 2 of P_4 and the terminal spines of this segment not so unequal in length as in *C. varicans;* and (5) no tiny inner spine on the distinct segment of P_5, although this tiny spine is often present in *C. varicans.*

Some authors (Kiefer 1929, etc.) have considered these differences constant enough and important enough to make *rubellus* a distinct species; Sars (1918) however said that *C. rubellus* Lilljeborg could "hardly be distinguished specifically" from *C. varicans,* and Gurney (1933) treats *rubellus* as a subspecies of *C. varicans.* I agree with Sars and Gurney in considering *rubel-*

lus as a subspecies of *C. varicans* until crossing experiments can be made. The Chapel Hill specimens undoubtedly belong to this subspecies, *C. varicans rubellus* (see the above description of the Chapel Hill specimens, of *C. varicans*, and of *C. v. rubellus*).

C. varicans Sars differs from *C. bicolor* Sars in the following points:— (1) the 5th thoracic segment of *C. varicans* is more laterally produced than in *C. bicolor* (see Sars, 1918); (2) the inner of the two middle terminal furcal setae in *C. varicans* is rather slender, noticeably longer than the outer median terminal seta, and at least as long as the furcal ramus and all abdominal segments combined, while this inner median terminal seta in *C. bicolor* is rather thick, only slightly longer than the outer median seta, and much shorter than the furcal ramus and all the abdominal segments combined (see Figs. 125 & 130); (3) the first antennae are of 11 to 12 (usually 12) segments in *C. varicans* and only 10 to 11 (usually 11) segments in *C. bicolor* (not an important point of distinction, because of the overlapping); (4) the outer terminal spine of endopod 2 of P_4 is usually at least half as long as the inner terminal spine in *C. varicans*, while this outer terminal spine is usually only about 1/4 as long as the inner terminal spine in *C. bicolor* (see Figs. 128 & 132); and (5) the seminal receptacle of *C. varicans* has approximately equal-sized anterior and posterior portions with the posterior portion projecting noticeably towards the posterior end of the animal (see Fig. 129), while the seminal receptacle of *C. bicolor* has the anterior portion transversely oval and much larger than the small posterior portion, and the whole receptacle is nearly as wide as the genital segment (see Fig. 131).

As mentioned in the distribution of *C. varicans* in North America, I consider Marsh's specimens of *"C. bicolor"* as specimens of *C. v. rubellus*. Marsh (1893) described his *"C. bicolor"* specimens as having 11-segmented first antennae (also present in *C. v. rubellus*) and with the longer of the two median terminal furcal setae as long as the abdomen (a characteristic of *C. varicans* and not of *C. bicolor*). Marsh's (1910) figures of the fourth foot of *"C. bicolor"* is certainly not like the foot described by Sars (1918) and Gurney (1933) for *C. bicolor*. Marsh drew the outer terminal spine of endopod 2 of P_4 about 2/3 the length of the inner spine—as in *C. varicans*. The average length of Marsh's *C. bicolor* specimens is given as 0.5 mm., but some of my *C. v. rubellus* collection are almost that short. Marsh (1910) says that in some individuals the position of P_5 on the last thoracic segment resembles *rubellus* Lilljeborg, but that the characters of the swimming feet, as given by Lilljeborg distinguish *bicolor* from *rubellus* (I can find little or no difference, except in endopod 2 of P_4, between the swimming feet of *rubellus* and *C. bicolor*). Marsh (1910) mentions an egg-bearing female *bicolor* that had antennae of 10 segments. It is possible that Marsh did have specimens of *C. bicolor*, but the *"C. bicolor"* specimens which he described and figured seem to be *C. v. rubellus* with 11-segmented first antennae.

Herrick's (1895) description of the copepod he identified as *"C. bicolor"* gives the measurements of various parts of the body of two specimens. In these specimens, the length of the longest terminal furcal seta is just about as

long (longer in one individual) as the furcal ramus and all the abdominal segments combined—a characteristic of *C. varicans* and not of *C. bicolor*. Herrick's figure of endopod 2 of P_4 and the furcal rami of supposed specimens of "*C. bicolor*" are certainly those of *C. varicans*. He says that the "basal segment" of P_5 protrudes decidedly as in *C. varicans*, while the seminal receptacle is rather elongate. One of Herrick's (1895) figures of "*C. bicolor*" is from a specimen from Alabama. He gives no other clue as to the distribution of his "*C. bicolor*," which we must consider as *C. varicans rubellus* having 11-segmented first antennae.

C. varicans or its subspecies *rubellus* is rather widely distributed in eastern North America and is usually abundant wherever found, although it may be overlooked because of its small size.

CYCLOPS BICOLOR Sars, 1863

(Figs. 130-132)

Cyclops bicolor Sars 1863, Forh. Vid. Selsk. Christiana **1862**:253.
Cyclops longicaudatus Poggenpol 1874.
Cyclops diaphanus (not Fischer) Rehberg 1880.
Cyclops brevisetosus Daday 1884.
Cyclops tenuicaudis Daday 1884.
Cyclops bicolor Schmeil 1892.
Cyclops bicolor Kiefer 1929.
Cyclops bicolor C. B. Wilson 1932.
Cyclops bicolor Gurney 1933.

I have been unable to examine specimens which could be assigned to *C. bicolor*. Those supplied me from Greenfield Pond, near Wilmington, N. C. (see Coker, 1938) are specimens of *C. varicans rubellus* Lilljeborg with 11-segmented first antennae. I do not doubt that *C. bicolor* occurs in America, but believe that most of the examples of "*C. bicolor*" collected in America are really specimens of *C. varicans rubellus* (see discussion of Marsh's and Herrick's specimens of "*C. bicolor*" at the end of the description of *C. varicans* Sars). Forbes (1897) says *C. bicolor* is rare in Wyoming, Illinois, Wisconsin, Michigan, and Minnesota, but he gives no description or figures, and I do not know whether he was confusing *C. v. rubellus* with *C. bicolor*. Wilson (1932) reported *C. bicolor* in small numbers from ponds near Woods Hole, Massachusetts. Wilson said *C. bicolor* is distinguished from *C. varicans* by having the two median terminal furcal setae more equal in length and shorter in proportion to the abdominal segments, and his drawings show this difference between the two species. I feel assured that Wilson's specimens are really *C. bicolor*. The species is rather widely distributed abroad. The following description is taken from Sars (1918), unless otherwise stated.

Body length of the female *C. bicolor* is about 0.8 mm. according to Schmeil (1892), scarcely exceeding 0.6 mm. according to Sars (1918), 0.6 to 0.8 mm. according to Kiefer (1929), and 0.6 to 0.7 mm. according to Gurney (1933). The body is rather stout and the 4th thoracic segment is not at all laterally produced. The 5th thoracic segment is very slightly laterally pro-

duced—even less produced than in *C. varicans*. Genital segment is not broad, but its anterior portion is rather protuberant ventrally.

Furcal rami are about as long as the last two abdominal segments combined according to Sars (1918), 4 to 4½ times as long as broad according to Kiefer (1929), and 4 to 5 times as long as broad according to Gurney (1933). The outer lateral furcal seta is inserted at a point about 75% to 80% of the distance from base to distal end of the ramus (Gurney, 1933). The innermost terminal furcal seta is about twice as long as the outermost terminal seta, according to Sars (1918), or more than twice as long as the outermost terminal seta, and nearly as long as the furcal ramus, according to Gurney (1933). The two median terminal furcal setae are rather thick, the inner median terminal seta not much longer than the outer median terminal seta and much shorter than the combined lengths of the furcal ramus and all the abdominal segments (see Fig. 130).

First antennae consists of 11 segments and are noticeably shorter than the first segment of the body. Wolf and Lilljeborg say *C. bicolor* may have 10 or 11 segments in the first antenna (see Spaeth, 1914, and Gurney, 1935). Marsh (1910) had an egg-bearing female with 10-segmented first antennae, but I am not sure that Marsh's copepod is a specimen of *C. v. rubellus* as were most of his specimens of "C. bicolor" (see discussion at end of my description of *C. varicans*). An aesthete at the middle of the 8th antennal segment extends to the distal end of the 8th segment (Gurney, 1933), but lies so closely to the segment that it cannot easily be seen.

Inner and outer rami of the swimming feet are of 2 segments. Spine formula of the terminal segments of the exopods of P_{1-4} is 3,4,4,3, the setal formula 5,5,5,5. Type F, Table 1, gives the complete armature of the swimming feet. Endopod 2 of P_4 is 2 to 2½ times as long as broad (Gurney, 1933). Inner terminal spine of endopod 2 of P_4 is shorter than the segment and about 4 or more times as long as the outer terminal spine which usually curves toward the inner side of the segment (see Fig. 132). The distal setae of endopod 2 of P_4 extend about to or a little beyond the distal end of the inner terminal spine (Gurney, 1933).

P_5 consists of only one distinct segment, the "basal segment" not being separated from the last thoracic segment, but still bearing an outer seta. The distinct segment is narrow and cylindrical and bears an apical seta. Sars (1918) says this segment has no trace of an inner spine, but Gurney (1933) says the inner spine is generally present but difficult to see.

The seminal receptacle (see Fig. 131) occupies most of the width of the anterior portion of the genital segment. The anterior portion of the seminal receptacle is somewhat transversely oval in form with a median indentation in its anterior margin, whereas the posterior portion of the seminal receptacle is narrow from front to back and often with its posterior margin indented (Gurney, 1933).

The thoracic segments are nearly colorless while the posterior part of the

body and the first antennae are golden yellow or orange in color according to Sars (1918) who, because of this color combination, gave the copepod its specific name.

The important differences between *C. bicolor* and *C. varicans* are brought out in the discussion at the conclusion of the description of *C. varicans*.

Since many of the records of *C. bicolor* were really records of *C. varicans rubellus* (see above and the description of *C. varicans*), the American distribution of *bicolor* is uncertain. It seems to have been found definitely near Woods Hole, Massachusetts, and possibly in Wyoming, Illinois, Wisconsin, Michigan, and Minnesota, but is undoubtedly rare in America.

CYCLOPS DIMORPHUS Kiefer, 1934
(Figs. 133 and 134)

Cyclops dimorphus Kiefer 1934, Zool. Anzeig. **107**:271.

In 1931 R. M. Bond sent Kiefer from the Salton Sea, California, copepods which proved to be a new species. Unfortunately, we were unable to obtain any specimens, so that the following description is taken from Kiefer's description and figures.

Length of the female is 1.1 to 1.2 mm. Furcal rami are elongated, averaging about 6 times as long as broad. Terminal furcal setae are proportionately short. The 11-segmented first antennae are about as long as the cephalothorax (about 350μ). Each of the rami of P_{1-4} is not quite twice as long as broad (about 56 : 30μ). This segment has one seta on the outer side, 3 setae on the inner side, a strong spine (50 to 60μ in length) on the inner distal end and another spine on the outer distal end. P_5 is very rudimentary. The basal segment found in many other copepods of the genus is lacking, as in *C. bicolor* and *C. varicans*, thus the outer seta is attached to the outer ventral side of the 5th thoracic segment. The structure which corresponds to the distal segment of such copepods as *C. viridis* and *C. vernalis* is a broad lobe bearing a seta on the outer side and a strong spine on the inner side (see Fig. 133). This spine is 14 to 17μ in length. Kiefer says the seminal receptacle resembles that of *Cyclops dengizicus* Lepeschk. The seminal receptacle of *C. dengizicus*, much like that of *C. bicuspidatus*, has a small roughly convex anterior portion and a large bag-like posterior portion (Kiefer 1926, 1929).

The male is 0.95 mm. long and the inner spine of P_5 is twice as long as in the female or is 32 to 33μ in length (see Fig. 134).

This species resembles *C. panamensis* Marsh (1913), which has been collected on the "savannas between Panama and Old Panama," in general form of P_5, segmentation of the first antennae and P_{1-4}, and slenderness of furcal rami; but it differs from that species in having an inner spine instead of an inner seta at the terminal end of endopod 3 of P_4, and a female body length of 1.1 to 1.2 mm. instead of 0.696 mm. Kiefer's description of *dimorphus* is not very complete, so there may be other differences between it and *panamensis*.

Kiefer placed *dimorphus* in the Subgenus *Metacyclops* Kiefer, but, as mentioned in the introduction, I place all members of this subgenus in the Subgenus *Microcyclops* Claus. Kiefer uses the form of P_5 as the principal means of distinguishing between many of his subgenera, but this foot is essentially the same (except in size and position of the inner spine) in *C. varicans* and *C. bicolor*, the type species of *Microcyclops*, and in *C. gracilis* Lillj., the type species of Metacyclops. Of course, the fifth foot of *C.* (*Metacyclops*) *dimorphus* is strikingly different from that of *C.* (*Microcyclops*) *varicans* (see Figs. 127, 133, & 134), but such species as *C.* (*Metacyclops*) *gracilis* Lillj. and *C.* (*Metacyclops*) *dengizicus* Lepeschkin have fifth feet that are intermediate in form between those of *varicans* and *dimorphus*. Because of this intergradation in form of P_5, I agree with Gurney in not considering Subgenus *Metacyclops* Kiefer as distinct from Subgenus *Microcyclops* Claus.

Dimorphus has been collected only from the Salton Sea, California.

DISCUSSION OF THE STRENUUS SUBGROUP

The subgenus Cyclops, to which *C. strenuus* and its close relatives belong, has often confused taxonomists because of the variability of its constituent species. Schmeil (1892), always conservative towards accepting new species, recognized only *C. strenuus* Fischer and *C. insignis* Claus. Later students have divided the *strenuus* described by Schmeil into various species and subspecies, but have generally recognized the distinctiveness of *C. insignis*. Lilljeborg (1901) divided the *strenuus* of Schmeil into *C. strenuus* Fischer, *C. kolensis* Lilljeborg, *C. miniatus* Lilljeborg, *C. scutifer* Sars, and *C. vicinus* Uljanin, while Sars (1918) recognized *C. strenuus* Fischer, *C. abyssorum* Sars, *C. lacustris* Sars, *C. scutifer* Sars, and *C. vicinus* Uljanin. *Kozminski* (1927), after extensive studies on the variability of the group, placed *C. abyssorum*, *C. lacustris*, and *C. miniatus* in the synonymy of *C. strenuus* Fischer and recognized *C. furcifer* Claus as a form of *C. strenuus* and *C. scutifer* and *C. vicinus* as distince species. In 1932, he made his *C. strenuus* forma *tatricus* a distinct species. Rzoska (1931) made *C. kolensis* Lilljeborg a good species, but otherwise agreed with Kozminski. Kiefer (1929) recognized *C. strenuus*, *C. abyssorum*, *C. lacustris*, *C. furcifer*, *C. scutifer*, and *C. vicinus*, making *tatricus* a form of *C. strenuus*, *miniatus* a synonym of *C. furcifer*, and *kolensis* a probable synonym of *C. strenuus*, but Gurney (1933) considered *tatricus* and *abyssorum* as subspecies of *C. strenuus*, *lacustris* a synonym of *C. strenuus*, and *C. kolensis* a distinct species; otherwise he agreed with Kiefer. I am inclined to accept Gurney's classification of this complex group, but, as I have examined only specimens of *C. strenuus*, *C. scutifer*, and *C. vicinus*, no definite conclusions can be reached. Only breeding experiments and examination of large numbers of specimens can clear up the taxonomic confusion.

Of this subgenus, only *C. scutifer* and *C. vicinus* have been definitely collected in America. Herrick's *insignis* record is not very satisfactory and all the available specimens of "*strenuus*" taken in America are really specimens of *C. scutifer*. See descriptions which follow.

CYCLOPS STRENUUS Fischer, 1851
(Figs. 135-142)

Cyclops strenuus Fischer 1851, Bull. Soc. Nat. Moscou, **24**(2):419, figs.
Cyclops brevicaudatus Claus 1857.
Cyclops lacustris Sars 1863.
Cyclops clause (not Heller or Poggenpol) Lubbock 1863.
Cyclops fedtschenkoi Uljanin 1875.
Cyclops helleri (juv.) Brady 1878.
Cyclops bodamicus Vosseler 1886.
Cyclops strenuus (part.) Schmeil 1892.
Cyclops strenuus Sars 1918.
Cyclops strenuus Kozminski 1927.
Cyclops strenuus Kiefer 1929.
Cyclops strenuus Gurney 1933.

CYCLOPS STRENUUS ABYSSORUM Sars, 1863

Cyclops abyssorum Sars 1863, Forh. Vid. Selsk. **1862**:238.
Cyclops pulchellus (not Sars) Brady 1878.
Cyclops ewarti (juv.) Brady 1888.
Cyclops abyssorum Kiefer 1929.
Cyclops strenuus abyssorum Gurney 1933.

For the preparation of this description, ten specimens of *C. strenuus* were examined, all collected February 13, 1933, at Meudon, near Paris, France, by Coker. I am not sure that the European type of *C. strenuus*, as described by Sars (1918), Kiefer (1929), and Gurney (1933) has ever been collected in North America. The specimens collected in North America and identified as *C. strenuus*, all seem to be specimens of *C. scutifers* Sars (see the description of *C. scutifer*). *C. scutifer* may eventually prove to be merely a subspecies of *C. strenuus*, but, at present, I agree with Sars (1918), Kozminski (1927), Kiefer (1929), and Gurney (1933) in considering *C. strenuus* and *C. scutifer* as separate species. Since *C. strenuus* Fischer may be present in North America, the following description of the above mentioned French specimens, with additional data from the authors mentioned, is given.

Body length of the female, exclusive of the furcal setae, is 1.50 to 1.70 mm., according to Sars (1918); 1.4 to 2.0 mm., according to Kiefer (1929); 1.66 to 2.35 mm., according to Gurney (1933); and 1.42 to 1.60 mm., according to our measurements of the French specimens. The species is robust in general body appearance (see Fig. 135), which shows an individual that was slightly flattened by a glass cover slip). The postero-lateral angles of the dorsa of the 4th and 5th thoracic segments are usually produced, though not into wing-like extensions as in *C. scutifer* (see Fig. 144) and *C. vicinus* (see Fig. 152). The shape of the 4th and 5th thoracic segments of the French specimens is shown in Fig. 135, which is very much like Sars' (1918) figure of these segments. *C. lacustris*, a form of *C. strenuus*, described by Sars as a separate species, has the 4th and 5th thoracic segments very slightly, if at all, laterally produced. Two of the French specimens seems to resemble *lacustris* closely in this respect, as well as in the proportions of the furcal rami. Posterior margins of the abdominal segments (except the last, which has its posterior margin armed with tiny spines) are slightly serrated. The proportions of the furcal

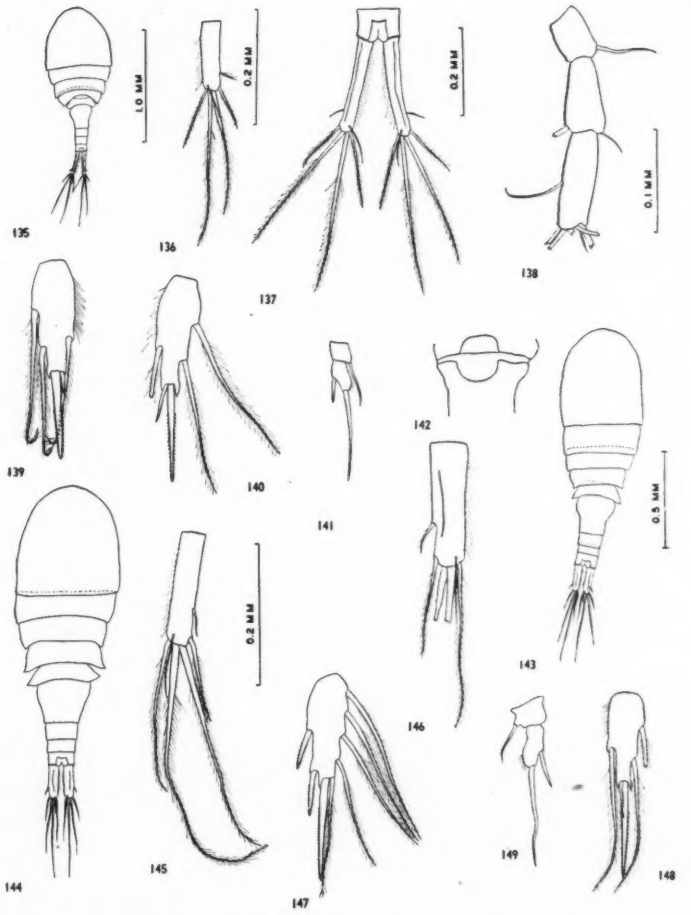


PLATE 11. Figs. 134-149. *Cyclops strenuus* Fischer, from Meudon, France. 135. Adult female, slightly flattened by cover-slip. 136. Unusually stubby furcal ramus. 137. Furcal rami (normal) and last abdominal segment. 138. 15th, 16th and 17th segments of first antenna of female. 139 and 140. Endopod 3 of P4. Same scale as 138. 141. P5. Same scale as fig. 138. 142. Seminal receptacle. Same scale as 137. *Cyclops scutifer* Sars from Bernard Harbor, N. W. T., Canada. 143 and 144. Adult females. 145 and 146. Furcal rami. 147. Exopod 3 of P4. 148. Endopod 3 of P4. 149. P5. (145-149 drawn to same scale.)

rami may vary greatly even in a single collection of *C. strenuus*. Kiefer (1929) gives the length of the furcal rami as being 5 to 6 times that of the width, while Gurney (1933) gives it as being usually 6 to 7 times that of the width. Quotient of length into width of the furcal rami of the French specimens is usually about 0.125 to 0.200 (5 to 8 times as long as broad), but 2 specimens have this quotient about 0.257 (slightly less than 4 times as long as broad, see Fig. 136). These two specimens, with the stubby furcal rami, seem to be of the *lacustris* type of *C. strenuus* (see discussion at end of this description). The small outer lateral seta is inserted at a point about 70% to 77% (73% to 87%, according to Gurney, 1933) of the distance from base to apex of the furcal ramus. Inner margins of the furcal rami are hairy and usually there is a dorsal longitudinal ridge present on each furcal ramus of the adult copepod. Often this ridge is difficult to see, and it may even be absent. The specimens having the stubby furcal rami showed scarcely a trace of this ridge (see Fig. 136). Relative terminal furcal setal lengths, innermost to outermost, give ratios such as 1.43: 2.91: 2.57: 1 and 1.54: 4.12: 3.46: 1. The innermost terminal furcal seta is shorter than the furcal ramus in all the French specimens, but according to Gurney (1933) it may occasionally be longer.

First antennae of 17 segments sometimes extend to the middle of the third segment of the body. Segments 15, 16 and 17 bear a line of very fine hyaline spines (see Fig. 138) very difficult to see unless the antenna is turned at just the right angle. An aesthete at the distal end of the 12th antennal segment extends to about the middle of the 14th antennal segment.

P_{1-4} have the inner and outer rami of 3 segments. Spine formula of the terminal segment of expopods of P_{1-4} is 3,4,3,3. Schmeil (1892) says the spine formula can be 3,4,3,3 or 2,3,3,3 or 3,3,3,3; but Gurney (1933) says that spine formulas for *C. strenuus* other than 3,4,3,3 are very rare. Setal formula of the terminal segment of exopods of P_{1-4} is always 5,5,5,5. Type G, Table 1, represents the complete armature of P_{1-4}.

Endopod 3 of P_4 is less than 3 times as long as wide, according to Gurney (1933), but in the French specimens, this segment is more than 3 times as long as wide (quotient of length of this segment into its width is about 0.301 to 0.318 in the French specimens). Quotient of length of segment into length of the longer terminal of the two terminal spines is 0.809 to 1.0. The inner terminal spine is 2.53 to 3.42 times longer than the outer terminal spine in the French specimens. Gurney (1933) says this spine is less than twice as long as the outer spines in his specimens. The setae of endopod 3 of P_4 extend about as far as the distal end of the inner terminal spine.

P_5 consists of 2 segments, the basal segment being only moderately broad, and with one seta at the outer side, and the end segment not especially slender and with an apical seta and a strong spine at the middle of the inner side. This spine does not usually exceed the entire length of the end segment (see Fig. 141).

The seminal receptacle is more or less longitudinally oval, the anterior por-

tion and the posterior portion making up the halves of the "oval" (see Fig. 142), one half of which may be broader than the other.

We can find no important difference between *C. strenuus* Fischer and *C. abyssorum* Sars Schmeil (1892), Uljanin (1901), Lilljeborg (1902), Kozminski (1927), considered *abyssorum* almost inseparable from *C. strenuus*. Sars (1918) still considered *abyssorum* a separate species– having longer first antennae than *C. strenuus*, longer and more slender furcal rami, longer terminal setae of the furcal rami, more slender segments of the swimming feet, and with a seminal receptacle shaped differently from that of *C. strenuus*. That *abyssorum* has longer and more slender furcal rami than *C. strenuus* is disputable, for Gurney (1933) said that the furcal rami of *C. strenuus abyssorum* are nearly always less slender than those of *C. strenuus*. Gurney (1933) also states that neither he nor Kozminski have seen specimens of *C. strenuus* which have terminal furcal setae as short as figured by Sars. Sars' (1918) figure of the seminal receptacle of *C. strenuus* shows the anterior portion as "transversely truncated" in front. Kiefer (1929) and Gurney (1933) show that the anterior end of the seminal receptacle of *C. strenuus* is more or less evenly rounded as in *abyssorum*.

Gurney (1933) considered *abyssorum* a subspecies of *C. strenuus* and said the furcal rami are generally shorter in *C. s. abyssorum* than in *C. strenuus*, that the innermost terminal furcal seta is never shorter than the ramus (and usually much longer) in *C. s. abyssorum*, but usually shorter than the ramus in *C. strenuus*, that endopod 3 of P_4 is more than 3 times as long as wide, with the inner terminal spine always longer than the segment, and more than twice as long as the outer terminal spine in *C. s. abyssorum*. However, in *C. strenuus* endopod 3 of P_4 is less than 3 times as long as wide with the inner terminal spine nearly always shorter than the segment, and less than twice as long as the outer terminal spine.

The French specimens agree with *C. strenuus*, as described by Gurney (1933) in every respect except in the proportions of endopod 3 of P_4 and the relative lengths of the terminal spines of endopod 3 of P_4. In these characters they are more like *abyssorum* as described by Gurney (1933). *Abyssorum* has the innermost terminal furcal seta always longer than the ramus, and the inner terminal spine of endopod 3 of P_4 always longer than the segment (Gurney, 1933). Such was not the case in the French specimens. Since the French specimens are like *C. strenuus* in some structures, and like *abyssorum* in other structures, and the differences between *C. strenuus* and *abyssorum* seem to have little taxonomic importance, these French specimens are here classified as *C. strenuus*, and no attempt to place them in a subspecies is made.

C. strenuus tatricus Kozminski is very close structurally to *C. s. abyssorum*. In 1932, Kozminski considered *tatricus* a distinct species According to Gurney (1933), it has been collected only from Tatra and the eastern Alps of Europe, and is characterized by having the "somite of leg 2 produced backwards on either side as a rounded lobe." His only figure of *C. s. tatricus* shows the postero-lateral angles of this first free thoracic segment produced backwards as described. It resembles *C. s. abyssorum* closely in other respects — has the

innermost terminal furcal seta longer than the ramus, and has the terminal segment of the endopod of P_4 three times as long as wide.

C. lacustris Sars is considered a limnetic variety of *C. strenuus* by Lilljeborg (1901) and Kozminski (1927), and we are inclined to agree with them, although we consider it only a phenotype of *C. strenuus*. Sars (1918) described *lacustris* as being distinct from *C. strenuus* in having: (1) the 4th thoracic segment not at all lateraly produced, and the 5th thoracic segment only slightly laterally produced; (2) the furcal rami rather short and not as slender as in *C. strenuus*, and lacking the dorsal longitudinal keel; (3) the innermost terminal furcal seta more than twice as long as the outermost terminal seta and longer than the furcal ramus; (4) the outer terminal spine of endopod 3 of P_4 only about 1/3 as long as the inner terminal spine; and (5) the distal segment of P_5 rather narrow, with its inner lateral spine very small.

Two copepods collected along with the French specimens and mentioned in the above description of the French collection, seemed to be very much like Sars' *lacustris* in points—(1) and (2) above, but P_5 and endopods 3 of P_4 were mashed and indistinct in the specimens. With respect to (4), the innermost terminal furcal seta is shorter than the furcal ramus, and only 1.4 times longer than the outermost terminal seta.

The differences between *C. strenuus* and *scutifer* Sars are given at the end of our description of the latter species.

As mentioned above and in our description of *C. scutifer* there are no authentic records of *C. strenuus* Fischer in America.

CYCLOPS FURCIFER Claus, 1857

Cyclops furcifer Claus 1857, Arch. Naturg. **23**(1):208, figs.
Cyclops lacunae Lowndes 1926.
Cyclops furcifer Kiefer 1927.

Cyclops furcifer Claus is regarded as a subspecies of *C. strenuus* by Kozminski (1927), but Gurney (1933) and Lowndes (1932) consider it a distinct species, the latter author not being able to cross his specimens with *C. strenuus*. According to Gurney (1933), it has been found only in certain European countries and in Algeria, but it is mentioned here in case the species should be found in North America and confused with *C. strenuus* or *C. scutifer*. The following description of *C. furcifer* is taken from Gurney (1933): body length 1.44 to 2.10 mm.; 4th and 5th thoracic segments only slightly laterally expanded, but each postero-lateral angle of thoracic segments 4 and 5 with rounded or pointed process slightly curved towards the anterior end of the animal; furcal rami, 8 to 9 times as long as wide, and with outer lateral seta not so near distal end as in *C. strenuus;* innermost terminal furcal seta shorter than ramus, and only slightly longer than outermost terminal seta; inner median terminal furcal seta much longer than outer median terminal seta; spine formula of terminal segments of exopods of P_{1-4} usually 2,3,3,3, but often 3,4,3,3; endopod 3 of P_4 less than 3 times as long as wide, and shorter than its inner terminal spine, which is about $2\frac{1}{2}$ as long as the outer

terminal spine; and finally, the body color is a conspicuous orange, although in mature females this color may be obscured by brown ovaries.

C. furcifer is not yet recorded from America.

CYCLOPS SCUTIFER Sars, 1863
(Figs. 143-149)

Cyclops scutifer Sars 1863, Forh. Vid. Selsk. Christiana **1862**:237.
Cyclops scutifer Lilljeborg 1901.
Cyclops strenuus (not Fischer) Marsh 1912, 1920.
Cyclops scutifer Kozminski 1927.
Cycloyps scutifer Kiefer 1929.
Cyclops scutifer Gurney 1933.

Seven specimens of *C. scutifer* were examined for the following description. These were collected ffrom a large lake, opposite Bernard Harbor, Northwest Territories, Canada, on May 6, 1924, and were loaned by the U. S. National Museum (Museum No. 58784). Marsh (1912) found specimens in collections made by Dr. B. W. Evermann, in Rock Pond, Axton, N. Y., on April 30, [year?]. Marsh, at that time, considered *scutifer, vicinus, miniatus* (= *furcifer*) and *kolensis*, as varieties of *C. strenuus;* consequently these New York specimens were identified as *C. strenuus*. Brehm, 1911, and Stephensen, 1913, reported *"C. strenuus"* from Greenland, and Marsh (1920) also found it in a collection labelled as being from a small lake in northern New York, in a collection from Cayuga Lake, New York, and in the contents of fish stomachs, caught in Oneida Lake, New York. I have seen neither specimens nor descriptions of the collection from Greenland, from the small lake in northern New York, Cayuga Lake and Oneida Lake, so I am not sure whether they could be classified as *C. scutifer* or not. Since, however, *C. scutifer* seems not uncommon in certain parts of North America and *C. strenuus,* as described by Sars (1918), Kiefer (1929), and Gurney (1933), has not been indisputably reported in North America, we presume that these specimens are *C. scutifer*. Marsh's 1912 description and figures of the Axton,New York, specimens certainly places these specimens in the species *C. scutifer*. Both Kiefer (1929) and Gurney (1933) considered Marsh's Axton collection as specimens of *C. scutifer*.

Marsh (1920) said that *"C. strenuus"* (*C. scutifer*) was probably the most common form of copepod found in the collections of the Canadian Arctic Expedition. It was taken at Cape Bathurst, July 26, 1916; Bernard Harbor, July 4, 1915, November 28, 1915, February 28, 1916, May 6, 1916, May 21, 1916, May 26, 1916, and June 13, 1916. Since Marsh's 1920 report, another collection of *C. scutifer* has been made for the U. S. National Museum at Bernard Harbor, Northwest Territories, Canada (May 6, 1924) and from this collection come the specimens which I examined. Willey has also reported *C. scutifer* from Canada (see Gurney, 1933). *Scutifer* is said to be one of the most common limnetic species in the Scandinavian countries.

Body length of the adult female, excluding the furcal setae, is 1.29 to 1.40 mm., according to Sars (1918), Kiefer (1929), and Gurney (1933). The

Axton, New York, specimens average 1.35 mm., the largest measuring 1.525 mm., while the Bernard Harbor, Northwest Territories, specimens vary from 1.625 to 1.9 mm., according to Marsh (1912 and 1920). The Bernard Harbor specimens vary from 1.40 to 1.62 mm., in length. The species is fairly robust in general body appearance, and the 4th and 5th thoracic segments are usually laterally expanded to form wing-like processes that end in points. The degree of expansion of these thoracic segments (especially the 4th) varies in the Bernard Harbor specimens (see Figs. 143 and 144). The genital segment is large, but the knob-like process on each side of the anterior part of the genital segment described by Sars (1918) have not been observed. Posterior margins of the abdominal segments (except the last, which has its posterior margin armed with tiny spines) are slightly or not at all serrated. The furcal rami are short—scarcely longer than the last two abdominal segments combined, according to Sars (1918) and about 4 times as long as broad, according to Kiefer (1929) and Gurney (1933). Quotient of length of furcal ramus into width is 0.212 to 0.270 (ramus some 3½ to 5 times as long as broad) in the Bernard Harbor specimens (see Figs. 145 & 146). The outer lateral furcal seta is attached at a point about 65% to 73% of the distance from base to apex of the ramus, and thus is usually more proximally placed than in *G. strenuus*. Inner margins of the furcal rami are hairy, and a dorsal longitudinal ridge may or may not be present on each furcal ramus (see Figs. 145 & 146). Relative terminal furcal setal lengths, innermost to outermost, give such ratios as 1.67: 2.86: 2.14: 1 and 1.77: 3.34: 2.52: 1, although one individual had the innermost terminal seta only about 1.55 times as long as the outermost. The innermost terminal seta is always longer than the furcal ramus (see Figs. 145 & 146).

First antennae are of 17 segments and extend about to the posterior margin of the 2nd segment of the body. The 15th, 16th and 17th antennal segments, as in other members of the subgenus *Cyclops*, bear a line of very fine hyaline spines. As mentioned before, these tiny spines are not always easy to see. An asethete at the distal end of the 12th antennal segment extends about to the middle of the 14th antennal segment.

The inner and outer rami of P_{1-4} are of 3 segments. Spine formula of the terminal segments of the exopods of P_{1-4} is 3,4,3, 3, the setal formula is always 5,5,5,5. Type G, Table 1, gives the complete armature of P_{1-4}.

Endopod 3 of P_4 is nearly 3 times as long as wide, according to Gurney (1933), but in the Bernard Harbor collection it is slightly more than 3 times as long as wide, or with quotient of length into width about 0.30 to 0.323. The inner terminal spine of endopod 3 of P_4 is some 1.0 to 1.14 times longer than the segment, and some 2.67 to 3.42 times as long as the outer terminal spine (see Fig. 148). The setae of endopod 3 of P_4 extend just beyond the distal end of the inner terminal spine.

P_5 and the seminal receptacles are indistinguishable from those of *C. strenuus*.

Practically the only differences found between the Bernard Harbor speci-

mens and *C. scutifer* as described by Sars (1918), Kiefer (1929), and Gurney (1933) are: — (1) In some of the specimens, the 4th thoracic segment is not as much expanded as in European *C. scutifer*, and (2) endopod 3 of P_4 is slightly more than 3 times as long as broad in our specimens and slightly less than 3 times as long as broad in Gurney's (1933) specimens.

Schmeil (1892) considered *C. scutifer* as a limnetic variety of *C. strenuus*, but Kozminski (1927) and others have shown *scutifer* to be a distinct species —differing from *C. strenuus* in the form of the 4th and 5th thoracic segments, in proportions of the furcal rami, in length of the innermost terminal furcal seta as compared to length of the ramus, and in length of the inner terminal spine of endopod 3 of P_4 as compared to length of the segment. These differences may seem to be slight, but they are conspicuous and apparently are constant.

Scutifer has been collected in small numbers in New York, eastern Canada, and possibly Greenland, and in large numbers in northwestern Canada (see above).

CYCLOPS VICINUS Uljanin, 1875

(Figs. 150-157)

Cyclops vicinus Uljanin 1875, Crust. Turkestan, p. 30, figs.
Cyclops pulchellus (not Koch) Brady 1878.
Cyclops lucidulus (not Koch) Vosseler 1886.
Cyclops vicinus Brady 1892.
Cyclops strenuus (part.) Schmeil 1892.
Cyclops vicinus Lilljeborg 1901.
Cyclops vicinus Sars 1918.
Cyclops vicinus Marsh 1920.
Cyclops vicinus Kozminski 1927.
Cyclops vicinus Kiefer 1929.
Cyclops kikuchii Smirnov 1932.
Cyclops vicinus Gurney 1933.

Nine North American specimens of *C. vicinus*, loaned by the United States National Museum, were examined in the preparation of this account, but several of them are so thickly covered with ecto-commensals (principally stalked protozoa of the vorticella type) that some of their structural details are difficult to see clearly.

Marsh's 1920 report of the collection made by the expedition stated that they were taken in a tundra pond at Collinson Point, Alaska, on June 13, 1914. Marsh says also that all *strenuus*-like specimens collected from Collinson Point had the spine formula of exopod 3 of P_{1-4} = 2,3,3,3 (which is a characteristic of *C. vicinus*) and that all *strenuus*-like specimens taken at Cape Bathurst and Bernard Harbor, Northwest Territories had the spine formula = 3,4,3,3 (a spine formula never reported for *C. vicinus*). No other North American records of *C. vicinus* have been reported.

Four specimens of *C. vicinus* from Loire, France, (11/11/32), given Coker by Dr. J. Roy were also examined. These had been labelled as *C. strenuus*, but thorough examination proved them to conform to the descriptions of *C.*

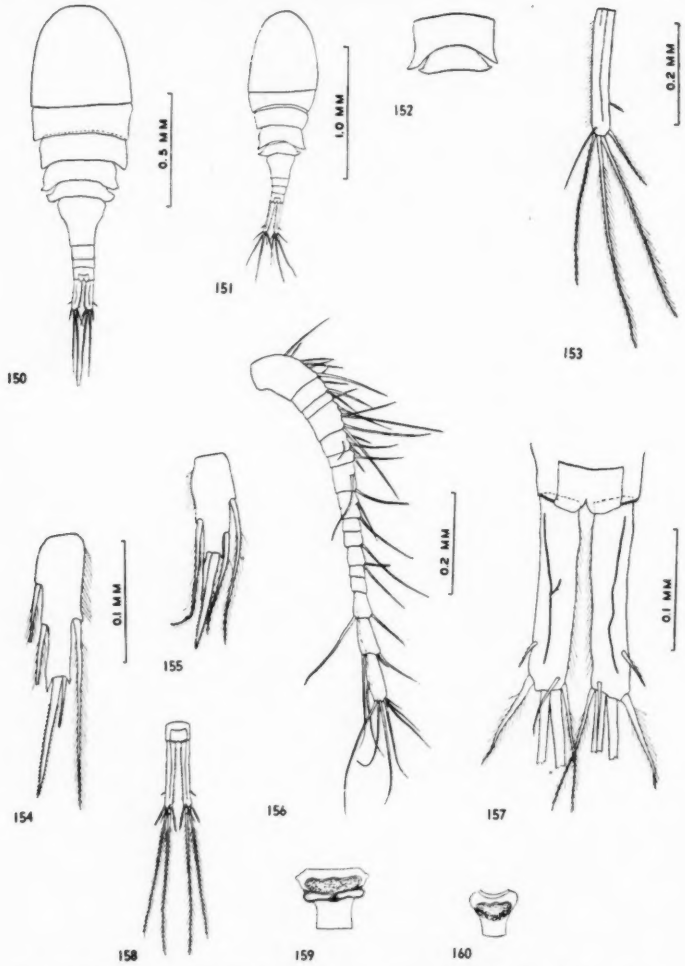


PLATE 12. Figs. 150-160. *Cyclops vicinus* Uljanin. 150. Adult female from Collinson Point, Alaska. 151. Adult female from Loire, France. 152. Fourth and 5th thoracic segments of female from Loire, France. Same scale as Fig. 150. 153. Furcal ramus of female from Loire, France. 154. Endopod 3 of P4 of Loire, France, female. 155. Endopod 3 of P4 of female from Collinson Point, Alaska. Same scale as Fig. 154. 156. First antenna of female from Loire, France. 157. Furcal rami of female from Collinson Point, Alaska. *Cyclops insignis* Claus. 158. Furcal rami and last abdominal segment. (After Sars, 1918). 159. Seminal receptacle with attached spermatophores. (After Sars, 1918). 160. Seminal receptacle (After Schmeil, 1892).

vicinus Uljanin by Sars (1918) and Gurney (1933) in practically every respect.

Body length of the female *C. vicinus* is about 1.7 mm. according to Sars (1918) and Kiefer (1929) and 1.44 to 1.85 mm. according to Gurney (1933). The French specimens measure 1.50 to 1.75 mm., whereas the Alaskan are only 1.07 to 1.30 mm. in length. The body is more slender in general appearance than that of *C. strenuus* Fischer. The 4th and 5th thoracic segments are laterally expanded into long wings that taper to points, the points of the 5th thoracic segment being somewhat curved toward the anterior end of the copepod (see Figs. 150, 151, & 152). Posterior margins of the abdominal segments (except the last, which has its posterior margin armed with tiny spines) are very slightly or not at all serrated.

Furcal rami of the Alaskan specimens are about 4.5 to 5.5 times as long as broad. $\left\{\frac{\text{Furcal width}}{\text{Furcal length}} = 0.176 \text{ to } 0.233.\right\}$ The rami are 7 times as long as broad according to Kiefer (1929) and 7 to 8 times as broad according to Gurney (1933). In the French specimens they are approximately 7 times as long as broad. (FW/FL = 0.13 to 0.14). The small outer lateral seta, of both French and Alaskan specimens, is inserted at a point 75% to 76% of the distance from base to apex of the furcal ramus. Inner margins of the furcal rami are hairy, while the dorsal side of each ramus bears a conspicuous longitudinal ridge. The "obliquely transverse inner branch" of this dorsal ridge described by Gurney (1933) as being generally characteristic of *C. vicinus*, is present on only one ramus of a single Alaskan specimen and is lacking in the French specimens (see Figs. 153 & 157). The short inner ridge near the base of the ramus and parallel to the dorsal ridge (see Gurney, 1933) has not been seen on the Alaskan specimens, but is present on one of the French specimens (see Fig. 153). Relative lengths of the terminal furcal setae, innermost to outermost, give ratios such as 1.41: 4.1: 3.65: 1 and 1.25: 5.44: 4.6: 1 in the Alaskan specimens. Thus the innermost terminal furcal seta is not quite 1½ times as long as the outermost terminal seta and noticeably shorter than the furcal ramus in the Alaskan specimens, but is over twice as long as the outermost terminal seta and longer than the furcal ramus in the French specimens, which agree with the figures of Sars (1918) and the descriptions of Kiefer (1929) and Gurney (1933).

The first antennae comprise 16 or 17 segments and extend about to the middle (and sometimes to the posterior margin) of the second segment of the body. The three most distal segments of the first antenna bear a line of fine hyaline spines (see Fig. 156). The 8th and 9th antennal segments are not completely separate, according to Sars (1918) and Gurney (1933). This is true of some of the French specimens (see Fig. 156), but those from Alaska seem to have 17-segmented first antennae. An aesthete is present at the distal end of the 12th segment (if we consider the 8th and 9th segments as distinct although they may not be completely separated) and it extends just beyond the middle of the 14th segment.

The inner and outer rami of P_{1-4} are of three segments. Spine formula of terminal segments of exopods of P_{1-4} is 2,3,3,3; the setal formula is 5,5,5,5. Type H, Table 1, gives the complete armature of P_{1-4}.

Endopod 3 of P_4 of my collection is approximately 3 times as long as broad or, to be more exact, the quotient of length into width is 0.314 to 0.352 in the Alaskan individuals and 0.275 to 0.30 in the French ones. Quotient of length of endopod 3 of P_4 into length of the longer of its two terminal spines is 0.90 to 1.0 in the Alaskan specimens and 0.96 to 0.983 in the French ones. The inner terminal spine is 2.0 to 2.38 times longer than the slim outer terminal spine in the Alaskan specimens and is 2.5 to 2.6 times longer than the outer in the French specimens (see Figs. 154 & 155). The setae of endopod 3 of P_4 extend just about as far as the distal end of the inner terminal spine. Endopod 3 of P_4 of our specimens agrees with Gurney's (1933) description of this segment in every respect.

P_5 is like that of *C. strenuus,* as is the seminal receptacle (see description of *C. strenuus* and Figs. 141 & 142).

As can be seen from the above description, the Alaskan collection of *C. vicinus* agree with Sars' (1918), Kiefer's (1929), and Gurney's (1933) descriptions of *C. vicinus* and with the French specimens of *C. vicinus* in most respects other than the furcal rami and their terminal setae. As mentioned in the above description, *C. vicinus* as described by these authors and the French collection have the furcal rami and the innermost terminal furcal setae relatively much longer than in the Alaskan ones. In spite of these differences, we believe the Alaskan specimens should be retained in the species *C. vicinus.*

The Alaskan *vicinus* collection definitely differs from the specimens of *C. scutifer* from Bernard Harbor, Northwest Territories, Canada, in general body appearance (see Figs. 143, 144, & 150), in furcal rami, in the relative lengths of the terminal furcal setae, in spine formula of the terminal segments of exopods of P_{1-4}, and in relative lengths of the terminal spines of endopod 3 of P_4.

C. kolensis Lilljeborg has the spine formula of exopods 3 of P_{1-4} the same as in *C. vicinus* (= 2,3,3,3), but its 4th and 5th thoracic segments are not expanded as in our French and Alaskan collections of *C. vicinus.* The furcal ramus of *C. kolensis* is short (only 4 to 5 times as long as broad) as in the Alaskan specimens of *C. vicinus,* but the innermost terminal furcal seta is nearly twice as long as the outermost terminal seta in *C. kolensis* and only about 1¼ times as long as the outermost seta in the Alaskan specimens. Some authors have regarded *kolensis* as a subspecies of *C. strenuus,* while Rzoska (1931) regards *kolensis* as a distinct species (see Gurney, 1933). *Kolensis* has not been reported from North America, but is mentioned here because it might be confused with *C. vicinis.*

Since *vicinus* has been collected only at Collision Point, Alaska, it is probably rare and local in distribution in North America.

CYCLOPS INSIGNIS Claus, 1857
(Figs. 158-160)

Cyclops insignis Claus 1857.
Cyclops insignis Schmeil 1892.
Cyclops insignis Sars 1918.
Cyclops insignis Kiefer 1929.

No specimens of this copepod were available. The following description is taken from Schmeil (1892), Sars (1918), and Kiefer (1929). Herrick (1895) was sent some copepods (identified by Herrick as *C. insignis*) from Long Island, New York, by E. A. Congdon, of Columbia College. This seems to be the only record of its occurrence in North America, if these do belong to *C. insignis* (see discussion at the end of this description).

The female is a large, robust copepod, being 2.5 to 5 mm. in body length, according to Schmeil (1892) and Herrick (1895), 2.60 mm., according to Sars (1918), and 2.5 mm., according to Kiefer (1929). The general body form is like that of *C. strenuus* Fischer but the postero-lateral angles of the dorsa of the last two thoracic segments are not quite so conspicuously produced laterally as in *C. strenuus* (judging from the figures of Schmeil, 1892). The genital segment is very broad anteriorly and abruptly constricted behind (Sars, 1918). Furcal rami are very long and slender, greatly exceeding the length of the last 3 abdominal segments combined, according to Sars (1918), and 8 times longer than broad, according to Kiefer (1929). A dorsal longitudinal ridge is present on each ramus, and the inner margins of each ramus are hairy. The outer lateral furcal seta seems to be slightly more proximally placed than in *C. strenuus* (according to Schmeil's and Sars' figures). Terminal furcal setae are not much elongated (see Fig. 158), the longest seta being hardly twice as long as the ramus, and the innermost only a little longer than the outermost seta and much shorter than the furcal ramus (Sars, 1918).

The first antennae are of 14 segments and extend about to the middle of the second segment of the body. The swimming feet have inner and outer rami of 3 segments. Spine formula of the terminal segments of the exopods of P_{1-4} is 2,3,3,3; and the setal formula of the same segments is 5,5,5,5. Type H, Table 1, gives the complete armature of P_{1-4}. Endopod 3 of P_4 is slender as in *C. strenuus* and its inner terminal spine is about twice as long as the outer terminal spine. P_5 seems to be like that of *C. strenuus*.

The seminal receptacle is short and broad, with an irregular anterior margin (see Figs. 159 & 160), and is not produced posteriorly, according to Schmeil (1892) and Sars (1918).

C. insignis closely resembles other members of the *strenuus* group in general body form, but its really large size, 14-segmented first antennae, very broad anterior portion of a genital segment that is abruptly constricted posteriorly, and absence of posterior portion of the seminal receptacle (this portion present in *C. strenuus, C. vicinis, C. scutifer, C. furcifer*, and others) clearly distinguish it from other species. *C. vicinus* Uljanin (and very rarely *C. strenuus*) has the same spine formula of the end segments of exopods of P_{1-4}

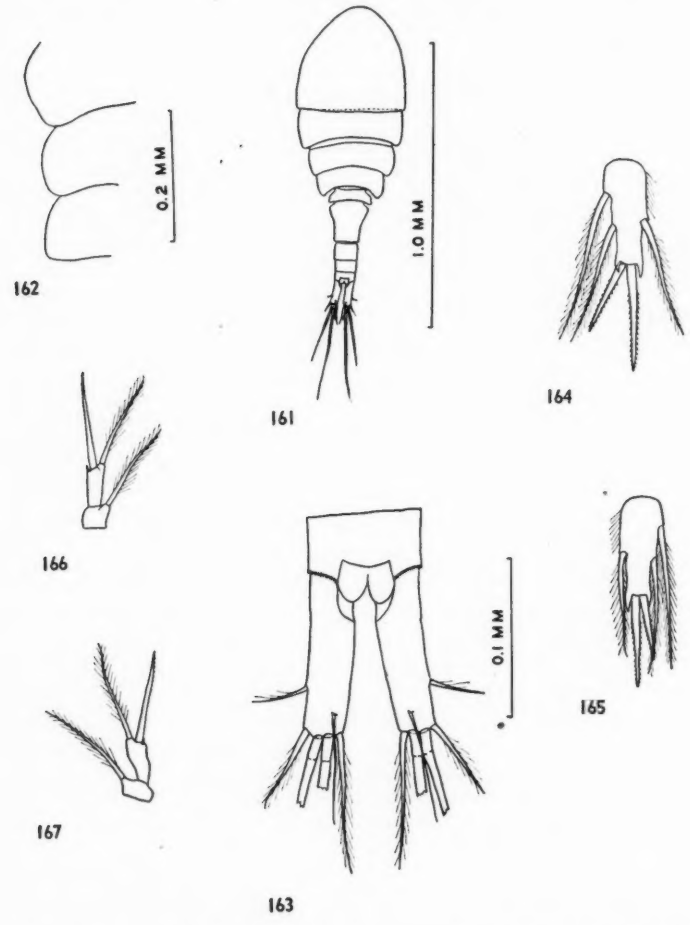


PLATE 13. Figs. 161-167. *Cyclops bicuspidatus navus* Herrick from a well 11 miles east of Pittsboro, N. C. 161. Adult female. 162. Left side of dorsum of 2nd, 3rd, and 4th thoracic segments. 163. Furcal rami and last abdominal segment. 164 and 165. Endopod 3 of P4. Same scale as 163. 166. Partial side view of P5 to shoe tiny spinule at base of slender spine on mesial side of 2nd segment. Same scale as 163. 167. P5. Same scale as 163.

(that is, 2,3,3,3,3), but *C. vicinus* is of much smaller size, has 17-segmented first antennae, a differently shaped genital segment and a different form of seminal receptacle.

Herrick (1895) in his description of *C. insignis* Claus confused it with *C. bicuspidatus* Brady, which also has the first antennae of 14 segments. He says that *insignis* is possibly a form of *C. strenuus*, in which the 8th segment failed to divide and suggests salinity of the water as a possible cause, since his specimens of *C. insignis* came from the brackish habitat, as usually does *C. b. lubbocki*. Presumably he was not well acquainted with the structure of *C. b. lubbocki* and not sure whether *lubbocki* was a form of *C. strenuus* or of *C. bicuspidatus;* otherwise, I can not explain why he thought the specimens almost identical with *C. b. lubbocki*, while his drawings are definitely of the *C. strenuus* type. Herrick draws the furcal rami each with a dorsal longitudinal ridge, the terminal segments of exopods of P_1 and P_4 with 5 setae each, and P_5 of the *strenuus* type. *C. bicuspidatus* (and *C. bicuspidatus lubbocki*) lacks the dorsal longitudinal ridge of the furcal ramus, has only 4 setae on each inner end segment of exopods of P_{1-4}, and has P_5 quite different from that of *C. strenuus* (see Figs. 98 & 102).

One of Herrick's drawings of *C. insignis* is puzzling. Fig. 11 of Plate XXII, for the outer ramus of the first foot as labelled, shows 3 spines on the terminal segment, although this segment in *C. insignis* is described by Schmeil (1892), Sars (1918), and Kiefer (1929) as having only two spines. Of course, the drawings may have been mislabelled and may be intended for the end segment of the exopod of P_2, but the 3rd exopod of P_2 should not be as stubby as that figured. Also, it is possible that *C. insignis* may occasionally have a spine formula of 3,4,3,3 or 3,3,3,3 instead of 2,3,3,3; but such has not been recorded. I am sure from Herrick's drawings that those specimens were of the *C. strenuus* type (Subgenus *Cyclops*), but since there have been no other records of *C. insignis* in North America, and since *C. strenuus* has been found in several localities, after Herrick's 1895 report, it is possible that the specimens were forms of *C. strenuus*, whose first antennae constitute only 14 segments each, as do those of *C. b. lubbocki*. *C. b. lubbocki* is said to be quite common in brackish water, but is also present in fresh water (Gurney, 1933) and it is questionable whether salinity has an effect on the segmentation of the first antennae. It is notable that Herrick's *C. insignis* specimens, with 14-segmented first antennae were 'within direct influence of the sea" (Herrick, 1895). Experimentation in the future may determine what influences the segmentation of the first antennae.

Measurement of the furcal rami and their terminal setae of Herrick's (1895) figure of a Long Island specimen, places the Long Island specimens closer to *C. insignis* than to *C. strenuus*, as far as these structures are concerned. The furcal rami are 9 times as long as broad in Herrick's figure and relative lengths of the terminal furcal setae, innermost to outermost, are 1.2: 7.66: 6: 1. The furcal ramus is 9.3 times as long as broad and relative lengths of the terminal setae, innermost to outermost, in Sars' (1918) figure of *C. insignis* are 1.2: 6.3: 5.7: 1; measurement of Schmeil's (1892) figure of

C. insignis gives the length of the furcal ramus as being 9.2 times as long as wide and relative lengths of the terminal furcal setae, innermost to outermost, as being 1.6: 9.6: 7.6: 1. No other described members of the *strenuus* group (subgenus *Cyclops*) have the two middle terminal furcal setae so much longer than the outermost and innermost terminal furcal setae. (Compare relative lengths of terminal furcal setae as given for *C. insignis* with those given for *C. strenuus, C. scutifer,* and *C. vicinus* in our descriptions of these species.

Even though Herrick's specimens show many close resemblances to *C. insignis,* Herrick's description and drawings do not give enough information to make certain that these Long Island specimens are really *C. insignis.* I conclude that the presence of this species in America is questionable

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Observations of Egg Laying Habits, Eggs, and Young of Land Mollusks on the Edmund Niles Huyck Preserve, Rensselaerville, New York

William Marcus Ingram

The following observations were made in the field and laboratory on the Edmund Niles Huyck Preserve, Rensselaerville, Albany County, New York. A research fellowship awarded the writer by the Scientific Advisory Committee enabled him to carry on this study from June 15 to September 1, 1940. A general description of the preserve has been given by Raney (1939). Previous reports on mollusks found on the preserve have been published, Ingram (1941a, 1941b, 1941c, 1941d, 1942).

Data on the early life history stages of *Stenotrema fraternum* (Say) were obtained. Studies were made of the eggs of the following snails, *Triodopsis dentifera* (Binney), *Triodopsis tridentata* (Say), *Ventridens intertextus* (Binney), *Zonitoides arboreus* (Say), and *Haplotrema concavum* (Say). Two snails, *Triodopsis dentifera* (Binney) and *Stenotrema fraternum* (Say) were observed depositing eggs in their natural habitat; it is believed that this report of egg laying in the field is the first to be reported in the literature. Photographic means employed here to illustrate eggs and young have not been used before. Even though much of the data are fragmentary, included observations should add to this little known phase of conchology. Simpson (1901), Foster (1936), and Van Cleave and Foster (1937) have given specific information of eggs and young of North American land snails. The former writer was concerned with *Triodopsis albolabris* (Say) and the latter writers with *Mesodon thyroidus* (Say).

Egg Laying by Stenotrema fraternum (Say)

On June 17 in a beech-hemlock forest area a *S. fraternum* was found depositing eggs at 3:30 p. m. This snail was on the top of a rotten beech stump which was 9 inches tall, in an open area of forest exposed to the sun. The anterior end of the body was greatly extended so that the eggs which were passing down the oviduct could be observed as nodule-appearing lumps on the body wall. The posterior foot region was firmly fastened to the substratum holding the animal in place. The eggs were deposited in a small depression in the stump 20 mm., long, 10 mm. high, and 12 mm. deep. The eggs were deposited one at a time. As they came to the mouth of the genital opening they were forced out into the crevice quickly. Approximately 120 seconds elapsed between the deposition of one egg and the appearance of another at the genital aperture. During this brief rest period between egg depositions the body wall at the genital aperture could be seen contracting and expanding, as though an attempt to force the eggs from the aperture by muscular contractions was being made.

After 7 eggs were deposited, and it appeared that no more were going to be laid since the snail had retracted its anterior end toward the shell, the individual and its eggs were removed from the stump and placed in a collecting vial. The vial was filled with moist humus, screened over by cheese-cloth, and then taken into the laboratory. On June 18 five additional eggs were found arranged in an oval cluster, bringing the total to 12 eggs laid in 2 days.

The eggs are round and of uniform size, approximately 2 mm. in diameter. The shell is elastic in character and is porcelain-white in color. The shell from its elastic nature is only a resistant protective membrane, and is without any apparent impregnation of calcium salts.

On July 16 six of the seven eggs laid June 17 showed well developed young within, the transluceny of the shell membrane enabled the observer to see the developing young. The whorls of the young shell were plainly visible. The yellow coloring of the developing shell, as seen through the egg shell, gave the eggs a yellowish appearance. The viscera could be observed also through the egg shell. No shell was visible on macroscopic examination July 13 when the eggs were observed although the liver mass could be observed through the egg shell.

On July 17, after an incubation period of 30 days, six of the seven eggs hatched. At this time a shell was visible on the retarded embryo. The six young, other than having worked their way through the egg shell, had not moved from the hatching area of the vial. On July 18 the six young were found 10 mm. from their hatching position; they were still clustered together. On July 19 four of the young had scattered from this cluster, having moved as follows: 1 moved 50 mm. toward the vial bottom, 1 moved 60 mm. and another 20 mm. toward the vial bottom, and 1 moved 100 mm. toward the top of the vial.

On July 19, two days after the above 6 had hatched, the seventh young emerged from its shell; the incubation period was 32 days.

Of the 5 eggs that were laid in the vial on June 18, three hatched on July 19, one left the egg shell on July 20, and the fifth individual was unhatched because of handling on July 18.

The above data indicate that there may be variations in the incubation period of eggs deposited by *S. fraternum* at one laying. This variation in the June 16 eggs was from 30 to 32 days. The eggs which were laid on June 18 varied in hatching time from 31 to 32 days.

The characteristics of the July 17 young were noted 2 days after they had hatched. The 6 young were of approximately uniform size; their wide diameter was 2.05 mm. (Fig. 1). The shell color was light horn-brown while that of the parent was grayish-brown. The shell was transparent so that the viscera, especially the liver mass, was visible through the shell. The beating heart was clearly observed. The shell was already beginning to assume the sculpture of the adult with the shell hairs well defined (Fig. 1) The tentacles of the young are more bulbous at their distal ends in relation to their length

than are those of the adult. The tentacle stalks of the young are lightly pigmented with blackish-grey, and the bulbous distal portion is without pigmentation. Due to such a pigment arrangement the black eyes in the center of the tentacles stand out in strong contrast with their lighter surroundings. The tentacles of the adult are entirely black, thus the color contrast between the eye and tentacle does not exist. The tentacles of the young are approximately .10 mm. in length, while those of the adult are 3 mm. long. The anterior half of the lateral foot surface and head are pigmented with a light greyish-black color; the posterior part of the foot is white without any obvious pigmentation. This is quite different from the adult condition where the entire body is found to be pigmented with greyish-black.

EGG LAYING OF TRIODOPSIS DENTIFERA (Binney)

On July 9 at 10:50 a. m. an adult *T. dentifera* was observed laying its eggs in a wet, rotten hemlock log. The snail had inserted its head and anterior foot region through a hole 4 mm. high by 6 mm. broad. The posterior foot region held the shell at right angles to the hole. The anterior foot region was of necessity compressed dorso-ventrally so that it could be inserted through

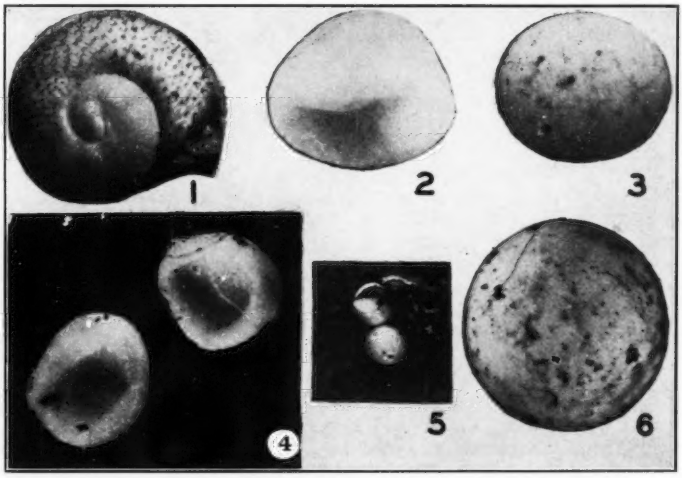

Fig. 1. Young of *Stenotrema fraternum* (Say) two days after hatching. Enlarged twenty-eight times.

Fig. 2. Egg of *Triodopsis dentifera* (Binney). Observe the "gastrula-appearing" indentation characteristic of newly laid eggs. Enlarged twenty-seven times.

Fig. 3. Egg of *Haplotrema concavum* (Say). Enlarged twenty-six and one half times.

Fig. 4. Eggs of *Triodopsis tridentata* (Binney). The characteristic indentation of newly laid eggs is present. Enlarged eighteen times.

Fig. 5. Eggs of *Zonitoides arboreus* (Say). Enlarged five times.

Fig. 6. Egg of *Ventridens intertextus* (Binney). Enlarged twenty-eight times.

the hole. This snail was observed during a twenty-minute interval before it withdrew its head from the cavity. It was not possible to see how many eggs had been deposited in this interval, for they could not be observed because of the narrow entrance. The snail was picked up although it obviously had not completed its egg laying. Round bulges on the right-anterior region of the body indicated that eggs remained in the oviduct. The oviduct was enlarged to such an extent that it was clearly visible as a white tube through the body wall.

The wood surrounding the cavity within the hemlock was next removed so that the eggs could be counted. The wood was so moist that water could be expressed by pressure from thumb and forefinger. The egg deposition chamber was 25 mm. long by 20 mm. tall by 12 mm. deep. The snail had deposited 16 eggs against the inner chamber wall, and with the exception of 3 which were at rest on the floor of the chamber all were in contact with one another. The eggs were piled 3 high in rows against the back wall of the log cavity, and were arranged to form roughly a rectangle. Not one of the eggs was perfectly round (Fig. 2); each had an indentation at one end making them "gastrula-appearing" in shape (Fig. 2).

The adult *T. dentifera* was brought into the laboratory and placed in a vial with moist earth. After a lapse of 3 hours 17 more eggs were laid, bringing the total number to 33 laid on July 9. The vial-laid eggs were of the characteristic shape of those that were laid in the field. These eggs formed an oval-oblong mass.

All eggs were of approximate uniform size, 3 mm. in diameter. They were white in color, and had a membranous egg shell (Fig. 2). On July 11, 2 days after laying, the eggs lost their indentation and assumed a spherical shape. The diameter of eggs after the evagination was approximately from 3.50 to 4 mm. on this date. Foster (1937) in his study of *Mesodon thyroidus* (Say) noted that the eggs of this species on being laid were concave but soon became almost spherical in form. He attributes the rounding out of the egg to absorbed moisture.

NOTES ON THE EGGS OF LAND MOLLUSKS

Eggs of Haplotrema concavum (Say).—On June 19 a captive *Haplotrema concavum* taken the day before deposited 7 eggs 10 mm. below the surface of the soil in a terrarium. On June 20 an additional 7 were laid beneath the soil. The eggs were not placed in a compact mass as in the case of the above species but were scattered. The eggs of this species are oval-oblong in shape and have a length of 2 mm. and a width of 1.50 mm. (Fig. 3). The egg shell is ivory-white in color and is non-elastic. One of the June 19 eggs hatched on September 1; the others of necessity were preserved on this date.

Eggs of Triodopsis tridentata (Say).—On August 17 one individual laid 6 eggs in a humus-filled vial. These were scattered over the surface of the humus. The adult made no attempt to conceal them; and from their arrangement on the surface of the humus they were apparently laid when the animal was in motion. They had not hatched on September 1 when they were pre-

served. When laid, these eggs varied from 2 to 2.10 mm. in diameter (Fig. 4). They possessed the characteristic indentation of the other Polygyridae eggs observed during the summer (Fig. 4). Two of them were triangular in shape; these possessed two indentations. One egg possessed 3 indentations and was rectangular in shape with angled ends.

Eggs of Ventridens intertextus (Binney).—One individual laid one egg in the laboratory on the upper surface of a piece of bark on July 17. This egg had not hatched by September 1 when it was broken open. The contents revealed that no embryo had been formed during this period. Several other eggs were collected in the field during early July. The diameter of the eggs (Fig. 5) which are spherical in outline varied from 2 to 2.25 mm. a well-formed calcareous, granulated shell seems to be typical for this species. The eggs were not indented.

Eggs of Zonitoides arboreus (Say). — On August 23, eggs and newly-hatched young of this snail were taken from beneath moist maple and beech leaf humus and wet, rotten beech bark. The 53 eggs observed were typically scattered about beneath the above-varying types of cover. In 2 instances 2 pairs of eggs were found side by side attached to leaves (Fig. 6). Seventy-six young were also found beneath the humus. Such data seem to indicate in the area studied that *Z. arboreus* typically lays its eggs at random beneath a moist protective covering, and on occasion deposits its eggs in pairs. Since no individual was observed in the egg-laying process, the above is speculative, but due to the position of the many eggs observed the inference should prove accurate. The eggs are oval-oblong in shape, and possess a calcareous shell. Their long diameter is 1 mm. and their short diameter varies approximately .80 to .90 mm. Bartsch and Quick (1926) referring to the eggs of this species state, "The eggs are deposited under dead, more or less moist bark, or similar situations, as small spherules, sometimes singly and at other times as small clumps; when in groups they are more or less agglutinized."

General Egg Data

Extensive field collecting and observations of snail eggs on the preserve indicate that the egg-laying period of the snails listed here extends at least over the period of the writer's stay. Egg laying began at an earlier date than June 15 for these snail species as evidenced by finding young whose size would indicate that they had hatched from eggs which had been deposited during the first two weeks in May.

Foster (1936) observed from field study that *Mesodon thyroidus* in a woodland on the Sangamon River flood plain near White Heath, Illinois, deposited eggs from May 1 to August 15. He considers that such a staggered egg-laying period enables this species to survive on the flood plain. Foster (1936) states, "There is little doubt in the mind of the writer that the long extended breeding season is a characteristic of *P. thyroides* [*Mesodon thyroidus*] which enables it to maintain itself as an abundantly represented species in a flood plain. The critical period in the perpetuation of the race extending

through such a considerable portion of the year enables survivors of catastrophic floods to quickly repopulate the flood plain." Van Cleave and Foster (1937) state regarding the extended egg-laying period of *M. thyroidus* in the above flood plain area, "Changes such as those produced by flood waters are usually of but short duration and could not wipe out an entire new generation as might be the case if all of the eggs were deposited at the same time."

The above observations of Foster and Van Cleave may be applied to the egg-laying period of the snails included here. Such a staggered egg-laying period no doubt is a great factor in increasing the chances of survival of a species whose eggs are exposed to a varying environment. Observations indicate, however, for the included species that a long egg-laying period is typical for theses nails whether they were found in flood plain areas or on higher ground not subjected to spring overflow.

Observations on the eggs of the following Polygyridae of the preserve *Triodopsis albolabris* (Say), *T. dentifera* (Binney), *T. tridentata* (Say), and *Stenotrema fraternum* (Say), showed that the situation in which the eggs were laid varied considerably, and that because of variations in habitats selected by adults some egg groups had a higher survival rate than others. Thus the environment in relation to species survival of the above Polygyridae is a constant factor in reducing a snail population at an early stage in its ontogeny.

The most common habitat in which eggs were found was beneath the humus covering of the forest floor, usually beside a log where the humus was piled at varying depths from 2 to 12 inches. In such areas abundant moisture was available, and the eggs were not in direct contact with shrew predators. Here they were protected above and below by the humus so that drainage would not affect them. Other favored egg depositories were hollow logs, log crevices, fallen bark, and soil beneath fallen trees; a few lots were found in slight depressions in the soil in open forest areas. Eggs were also found on top of stumps and decaying logs; eggs in such situations were exposed to the drying effects of the sun. Of 12 egg masses so observed during the summer none survived over a period of 7 days from the time they were located. Three disappeared at the end of the third day of observation, and the others were desiccated at varying times up to 7 days.

That eggs, which are associated with log cavities or those that are deposited beneath logs on the ground, are preyed upon by the short-tailed shrew, *Blarina brevicauda talpoides*, the writer has no doubt. A freshly-trapped *Blarina*, taken from beneath a log, yielded eggs of *T. albolabris* which were wedged in the pharyngeal region of the throat. This shrew was doubtlessly feeding in the vicinity of the snap-back mouse trap before his capture.

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MILLS COLLEGE, CALIF.

The Oedogoniales of Florida

L. H. Tiffany

During the months of January and February, 1931, the writer made several hundred collections of filamentous freshwater algae from the lakes, ponds, pools, streams, canals, and ditches of Florida. The samples have been examined critically for representatives of the algal order, Oedogoniales. The three genera of the single family, Oedogoniaceae, are represented in Florida by the following numbers of different species and varieties, Oedogonium 89[1], Bulbochaete 16[1], Oedocladium 1.

The single species of Oedocladium was reported by Knapp (1933) from a sample of soil from Sanford. The genus has been found elsewhere in America so far only from Massachusetts, New Jersey, and Virginia by Lewis (Tiffany 1930, 1937); from North Carolina by Whitford (1938); from Puerto Rico by Tiffany (1936). Vegetative material has been seen in the Boston Mountain area of Arkansas by Couch (1942). This restricted distribution of Oedocladium suggests a possible correlation with the geological history of the habitats. All species except *O. hazenii* are terrestrial, usually found growing with Vaucheria, moss protonema, or liverworts. It seems a safe prediction that persistent search will reveal the presence of other species of Oedocladium in Florida.

The number of species of Oedogonium and of Bulbochaete from Florida looms large in relation both to the total number known for these genera and to the total number ever collected from any comparable geographic area in North America. When it is considered also that the collections represent merely the months of January and February of a single year and that species of these genera are identifiable only in the fruiting stages, the unusual richness of the State (or at least certain parts of it) is almost phenomenal.

Data on distribution are too inadequate to warrant valid comparisons with other sections of the country, but a few statements, limited to Oedogonia, may be of interest. Over one-third of the species of Oedogonium from Florida also occur in other subtropical areas, including Puerto Rico, Mexico, Brazil, and the West Indies. Eighteen of these "subtropical forms" occur in Puerto Rico alone. On the other hand nearly a third of the Floridan species has also been reported from each of the States of Iowa, Illinois, Michigan, and Ohio; about one-fourth from Massachusetts; nearly one-half from the Scandinavian Countries and Finland; and only ten species are not reported north of the thirty-sixth parallel of latitude in North America. It will be noted immediately that all these geographic regions, selected somewhat at random, are areas in which algologists have made intensive studies over many years.

1 These numbers include a few species reported by Collins (1909) and not seen by the present writer. They are included to bring the summary up-to-date.

The discovery of fruiting *Oedogonium reinschii* was reported from Florida by the writer in 1935. This species occurs in the vegetative condition and generally produces zoospores in such diverse geographic locations as Massachusetts, New York, Michigan, Iowa, Virginia, British Columbia, England, France, Sweden, Paraguay, and southern Brazil. Only from Florida has material been collected to date with antheridia, oogonia, sperms, eggs, and oospores, and this occurred during the month of May.

A pond scarcely more than an acre in area located in a cypress "strand" just south of Arcadia yielded thirty-one species and two varieties of Oedogonium and Bulbochaete.[2] This large number was not equalled anywhere else in the State, although most of the ponds in the cypress swamps were highly productive. It is very difficult to understand the diversity of yield in what appear to be very similar bodies of water. Nearly every algologist has had the experience of discovering a single pond, or other habitat, in a given area unusually rich in species when compared with apparently similar habitats in the same area. Until biological investigations can be carried out in different localities over a period of years, the relations of environmental factors to algal productivity as well as the accident of introduction through carrier agents such as birds, can be surmised but not accurately gauged.

The abundance of filamentous algae in praire ponds makes one think of nearby rich soils and fairly long growing seasons. Similar high yields from northern Europe may be related to high light intensity and abundance of mineral salts. If one may judge from both entomological investigations on insects and botanical surveys of flowering plants, the number of species of Oedogoniales might be expected to be large in tropical and subtropical waters. It must be borne in mind, however, that freshwater habitats the world over may be quite comparable except for seasonal variations: high algal productivity to indifferent to none in the same area. Most species of Oedogonium and Bulbochaete are annuals in the North Central States (Tiffany and Transeau, 1927) having fairly definite periods of sexual reproduction. Some undoubtedly produce more than one "brood" in a single year. Perhaps more species than we know about, however, may be able to survive the winter seasons in a partly dormant vegetative condition, resuming active growth the following spring. New filaments could arise in such plants wholly through their zoosporic activity. The same periodicities recorded for these temperate areas do not obtain in subtropical habitats.

In addition to such variables in the life cycles of these filamentous algae, a long-term periodicity has sometimes been observed, even extending over periods as long as five to eight years. This would seem to be due to a prolonged oosporic dormancy or to rhythms of high productivity alternating with a productivity so low as to be overlooked entirely. In a species studied under

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2 Oedogonium: *acrosporum, armigerum, boscii, brasiliense, completum, confertum, costatum, crassum, crispum* v. *hawaiense, cyathigerum, decipiens* v. *africanum, gracilius, inconspicuum, longicolle, minus, oelandicum, plagiostomum, porrectum, punctatostriatum, pusillum, reinschii, senegalense, sexangulare, spirostriatum, taphrosporum, wyliei.* Bulbochaete: *alabamensis, bullardi, congener, intermedia, rectangularis, setigera, varians.*

laboratory conditions, Mainx (1931) found that the mature oospores were dormant twelve months before germination could be induced. Obviously a second generation occurring naturally in some species in the autumn must develop from oospores whose dormant period is less than a year.

No authentic instance of hybridization in the Oedogoniales has so far been reported. Hybrids are of course possible and many indeed have occurred. This would not preclude the living together of many species in a pond or lake without interbreeding. The production and liberation of sperms occur apparently in each species at certain very limited times. The eggs ripen also within similarly limited periods. The oogonial apertures not open at such times make fertilization impossible, because the sperms live only a few hours (Spessard, 1930). For all we know, many of the species may be cross-sterile. Interbreeding would thus seem to be the exception rather than the rule. The preponderance of oogonial filaments over antheridial filaments in many species may indicate parthenogenetic development of unfertilized eggs. Nothing is known of changes of gene frequency, of chromosomal aberrations, or of mutations in general in this algal group.

It seems likely that numerous recognizably different species may be found in a single pond and may live there unaltered genetically for long periods of time. The simultaneous germination of oospores of different lengths of dormancy might account for the presence of the thirty-three species of Oedogoniales from a single pond, noted above. Given the permanency of the habitat, the proper environmental conditions, and the accident of disperal or the rise of the species by some heritable variation, there seems to be little question but that many species might often be found together.

These intriguing problems cannot all be solved in a day or a year or even a lifetime, but the patient accumulation of ecological, physiological, morphological, and genetical data on the Oedogoniales will some day make it possible for us to see through much of the haze that now surrounds the explanation for the distribution of the members of this algal group.

The State of Florida lies within the Coastal Plains province, and its topography is fairly even. The northern part is essentially temperate, with the southern tip as nearly tropical as continental United States affords. Florida is young geologically, none of its surface older than the Eocene and a considerable part either Pleistocene or recent. The underlying rock is mostly limestone. In general the soil is poorly drained, the swamps are numerous, the many lakes are quite shallow, and the streams very sluggish. The bulk of the rainfall occurs in summer and autumn with a much drier season in winter and spring.

The northern and north-central part of the State may be included biotically in the southeastern evergreen forest formation, with the magnolia hammocks occupying certain smaller areas. There are swampy areas in the extreme northeastern tip of the State. The flatwoods in the central part of the State, as well as in eastern coastal areas extending further south, are poorly drained, fairly

flat areas, underlaid with a layer of hardpan and having fairly acid soils. The shallow depressions in the flatwoods area are the cypress swamps, the largest of which is Big Cypress in Collier County southwest of Lake Okeechobee. These depressions are usually under water, but may go dry. They often appear as numerous small inter-connected ponds. The remainder of the State, except for the more truly tropical forest areas of the Keys, is occupied by grassy swamps, savannas, and salt marshes, within which lies the Everglades.

The cypress swamps in the flatwoods areas of the counties of Lee, Charlotte, DeSoto, Henry, Glades, Highlands, Osceola, and Palm Beach yielded a greater number of species of the Oedogoniaceae than any other region in the State. Next in importance in yield of these algae were ponds and roadside ditches in Collier County and in the eastern part of Dade County. The Everglades region, except for a few species collected along the Tamiami Highway, yielded little or nothing. Lake Okeechobee was likewise almost barren of these filamentous algae, and few species were collected from any of the large lakes. Several species having ornamental spores occurred in small pools and ponds on Long Key. Perhaps third in productiveness was the coastal flatwoods from Daytona Beach to Jacksonville. The northwestern part of the State was not sampled sufficiently for discussion here, but the out-of-state collections made along the Gulf coast have not yielded large numbers of species.

The systematic analysis which follows includes complete keys and descriptions of all the species of Oedogonium, Oedocladium, and Bulbochaete known to occur in Florida. This complete analysis is given with the hope that it may prove useful in further algal surveys of the State.

Bulbochaete

KEY TO SPECIES

1. Wall of oospore costate 2
1. Wall of oospore scrobiculate 7
1. Wall of oospore smooth ..... 1. *B. minuta*
1. Wall of oospore crenulate ..... 2. *B. crenulata*
1. Wall of oospore reticulate-scrobiculate ..... 3. *B. gigantea*
1. Wall of oospore variable 8
   2. Oogonium 32-40μ in length ..... 4. *B. pygmaea*
   2. Oogonium 43-63μ in length 3
   2. Oogonium 70-96μ in length 6
3. Vegetative cell cylindrical or nearly so 4
3. Vegetative cell repand ..... 8. *B. repanda*
   4. Oospore ellipsoid 5
   4. Oospore ovoid ..... 5. *B. varians*
5. Diameter of oogonium 28-32μ ..... 6. *B. hiloensis*
5. Diameter of oogonium 32-39μ ..... 7. *B. rectangularis*
   6. Diameter of oospore 44-54μ ..... 9. *B. insignis*
   6. Diameter of oospore 54-64μ ..... 10. *B. bullardi*
7. Oogenium 31-40μ in length ..... 11. *B. intermedia*
7. Oogonium 40-48μ in length ..... 12. *B. congener*
7. Oogonium 56-65μ in length ..... 13. *B. setigera*
7. Oogonium 70-88μ in length ..... 14. *B. alabamensis*
   8. Oospore-wall smooth to scrobiculate ..... 15. *B. polyandria*
   8. Oospore-wall scrobiculate to crenulate ..... 2. *B. crenulata*

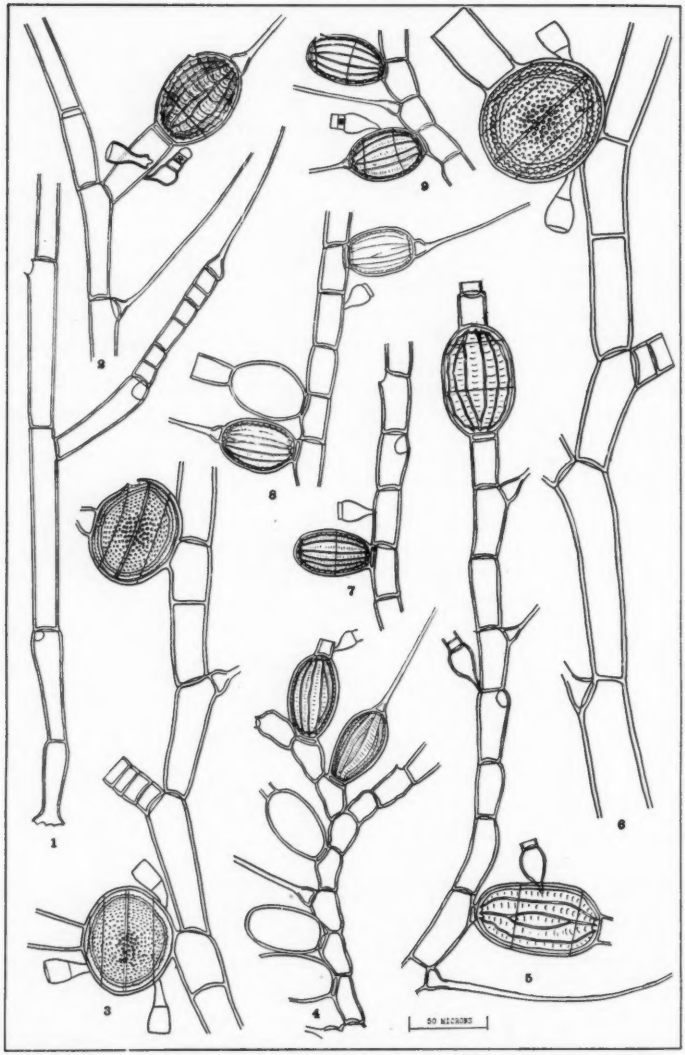

PLATE 1.—Figs. 1, 2. *Bulbochaete bullardi* Transeau & Tiffany. 3. *B. setigera* (Roth) Agardh. 4. *B. repanda* Wittrock. 5. *B. insignis* Pringsheim. 6. *B. alabamensis* Transeau & Brown. 7. *B. hiloensis* (Nordstedt) Tiffany. 8. *B. rectangularis* Wittrock. 9. *B. varians* Wittrock. (Fig. 7 redrawn from Hirn).

1. B. MINUTA West & West

Dioecious, nannandrous, gynandrosporous; oogonium depressed-globose, patent or erect, below the androsporangium; division of oogonium median or nearly so; suffultory cell without division, or with division basal; oospore-wall smooth; androsporangium unicellular, epigynous; dwarf male on suffultory cell, antheridium exterior, unicellular, stipe twice as long as antheridium, curved; vegetative cell 9-12 x 18-35μ; oogonium 29-35 x 24-27μ; oospore 27-33 x 22-25μ; androsporangium 9-11 x 6-9μ; dwarf male 6-7 x 18-20μ.

Swamp east of Buckingham. Pl. 2, Fig. 15.

2. B. CRENULATA Pringsheim

Dioecious, nannandrous, gynandrosporous; oogonium subdepressed-globose, patent, below terminal seta or androsporangium, or rarely vegetative cell; division of suffultory cell median or slightly below; spore-wall scrobiculate to crenulate; androsporangia epigynous or scattered, 1-5; dwarf male on or near oogonium, antheridium interior, stipe slightly curved, shorter than antheridium; vegetative cell 16-20 x 32-70μ; oogonium 43-48 x 35-43μ; oospore 40-46 x 33-40μ; antheridium 10-15 x 7-10μ; drawf male 9-10 x 24-26μ.

Roadside south of Ft. Myers. Pl. 2, Fig. 18.

3. B. GIGANTEA Pringsheim

Dioecious, nannandrous, idioandrosporous; oogonium subdepressed-globose or rarely depressed-oboviform-globose, patent, below terminal seta, rarely below vegetative cell; division of suffultory cell slightly below median; outer wall of oospore reticulate-scrobiculate; androsporangia 1-5; drawf male slightly longer than the oogonium on which it develops; antheridium interior; stipe about twice as long as antheridium, curved; vegetative cell 24-32 x 50-112μ; oogonium 60-70 x 50-58μ; oospore 58-69μ x 48-56μ; androsporangium 18-20 x 10-14μ; dwarf male stipe 10-13 x 28-45μ; antheridium 13-14μ x 20-30μ.

"Fla." (Collins). Pl. 2, Figs. 10, 11.

4. B. PYGMAEA Pringsheim

Dioecious, nannandrous, gynandrosporous; oogonium ellipsoid, patent, below terminal seta or vegetative cell; outer wall of oospore longitudinally ribbed; suffultory cell without division; androsporangia subepigynous or scattered, 1-? celled; dwarf male near oogonium, antheridia exterior, 1-3; vegetative cell 11-15 x 8-15μ; oogonium 22-27 x 32-40μ; oospore 20-23 x 30-38μ; androsporangium 7-10 x 6-9μ; dwarf male stipe 11-12 x 15-19μ; antheridium 7-8 x 7-8μ.

Cypress swamp west of Buckingham. Pl. 2, Fig. 16.

5. B. VARIANS Wittrock

Dioecious, nannandrous, gynandrosporous; oogonium ovoid, patent or erect, below terminal seta or below androsporangial cell; outer oospore-wall

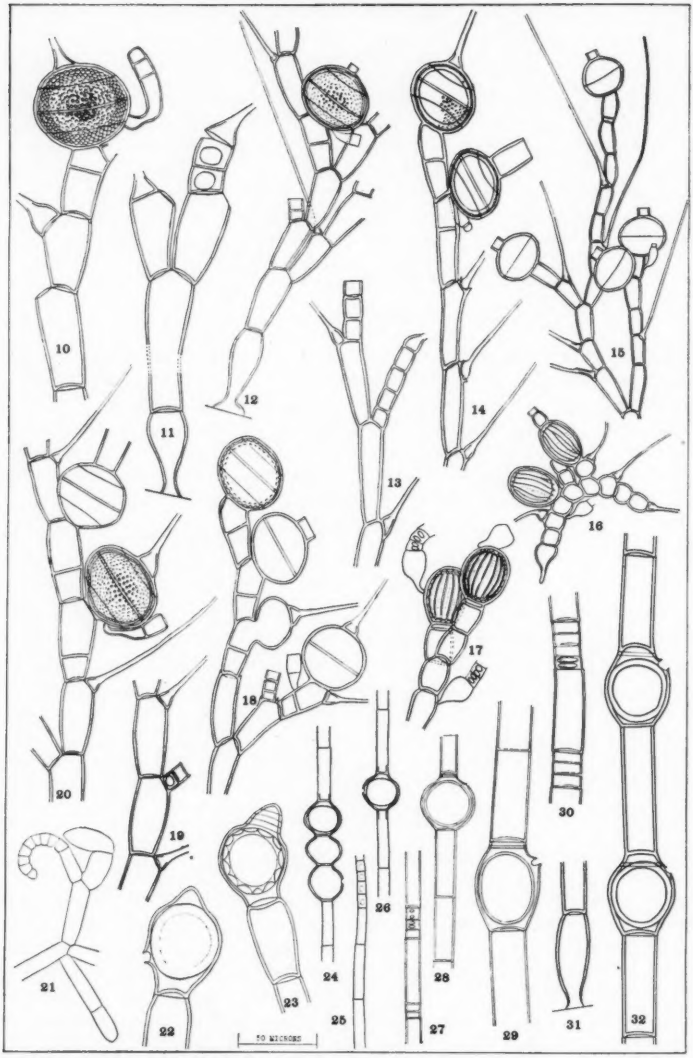

PLATE 2.—Figs. 10, 11. *Bulbochaete gigantea* Pringsheim. 12. *B. intermedia* DeBary. 13, 14. *B. polyandria* Cleve. 15. *B. minuta* W. & G. West. 16. *B. pygmaea* Pringsheim. 17. *B. varians* var. *subsimplex* (Wittrock) Hirn. 18. *B. crenulata* Pringsheim. 19, 20. *B. congener* Hirn. 21-23. *Oedocladium wettsteinii* E. Knapp. 24-26. *Oedogonium rufescens* Wittrock. 27, 28. *O. franklinianum* Wittrock. 29, 30. *O. gracilius* (Wittrock) Tiffany. 31, 32. *O. plagiostomum* Wittrock. (Fig. 15 redrawn from West; Figs. 12-13 from Knapp; Figs. 31, 32 from Hirn).

longitudinally ribbed, ribs serrate; androsporangia scattered, epigynous or hypogynous, 1 or 2; dwarf male on or near the oogonium, antheridia exterior, 1-3; vegetative cell 17-22 x 22-33μ; oogonium 30-36 x 44-54μ; oospore 28-34 x 42-52μ; androsporangium 14-17 x 14-18μ; dwarf male stipe 14-16 x 24-27μ; antheridium 8-10 x 6-7μ.

Roadside stream near Ft. Myers; cypress swamp south of Arcadia; swamp east of Bayshore. Pl. 1, Fig. 9.

5a. Var. SUBSIMPLEX (Wittrock) Hirn

Smaller in nearly all parts; ribs of oospore serrulate or smooth; vegetative cell 13-18 x 16-34μ; oogonium 26-30μ x 39-46μ; oospore 24-28 x 37-44μ; androsporangium 10-14 x 7-16μ; dwarf male stipe 11-14 x 15-24μ; antheridium 7-8 x 5-7μ.

Roadside stream near Ft. Myers; north of Naples; east of Taft. Pl. 2, Fig. 17.

6. B. HILOENSIS (Nordstedt) Tiffany

Dioecious, nannandrous, gynandrosporous; oogonium ellipsoid, patent or erect, below terminal seta or androsporangium or more rarely vegetative cell; outer wall of oospore longitudinally costate; androsporangia generally epigynous, 1-?; dwarf male near oogonium; antheridia exterior, 1-4; vegetative cell, subrectangular in section, 14-20 x 24-48μ; oogonium 28-33 x 43-51μ; oospore 26-30 x 38-45μ; androsporangium 12-17 x 13-16μ; dwarf male stipe 13-17 x 22-27μ; antheridium 8-9 x 5-7μ.

Roadside west of Alva. Pl. 1, Fig. 7.

7. B. RECTANGULARIS Wittrock

Dioecious, nannandrous, gynandrosporous; oogonium ellipsoid, patent or more rarely erect, below terminal seta or androsporangium or more rarely vegetative cell; outer oospore-wall longitudinally ribbed; androsporangia scattered or epigynous, 1-?; dwarf male near or occasionally on oogonium; antheridia exterior, 1-4; vegetative cell, subrectangular in section, 16-23 x 20-46μ; oogonium 32-39 x 45-63μ; oospore 29-37 x 43-61μ; androsporangium 13-16 x 10-27μ; dwarf male stipe 14-18 x 22-27μ; antheridium 8-10 x 5-7μ.

Roadside south of Ft. Myers; roadside north of Buckingham; cypress swamp south of Arcadia. Pl. 1, Fig. 8.

8. B. REPANDA Wittrock

Dioecious, nannandrous, gynandrosporous; oogonium suboblong-ellipsoid, patent or erect, below androsporangium, terminal seta,or vegetative cell; outer oospore-wall longitudinally ribbed; androsporangia epigynous or subepigynous, 1-?; dwarf male near or on oogonium; antheridia exterior, 1-3; vegetative cell, frequently repand, 12-17 x 24-60μ; oogonium 26-36 x 43-58μ; oospore 21-33

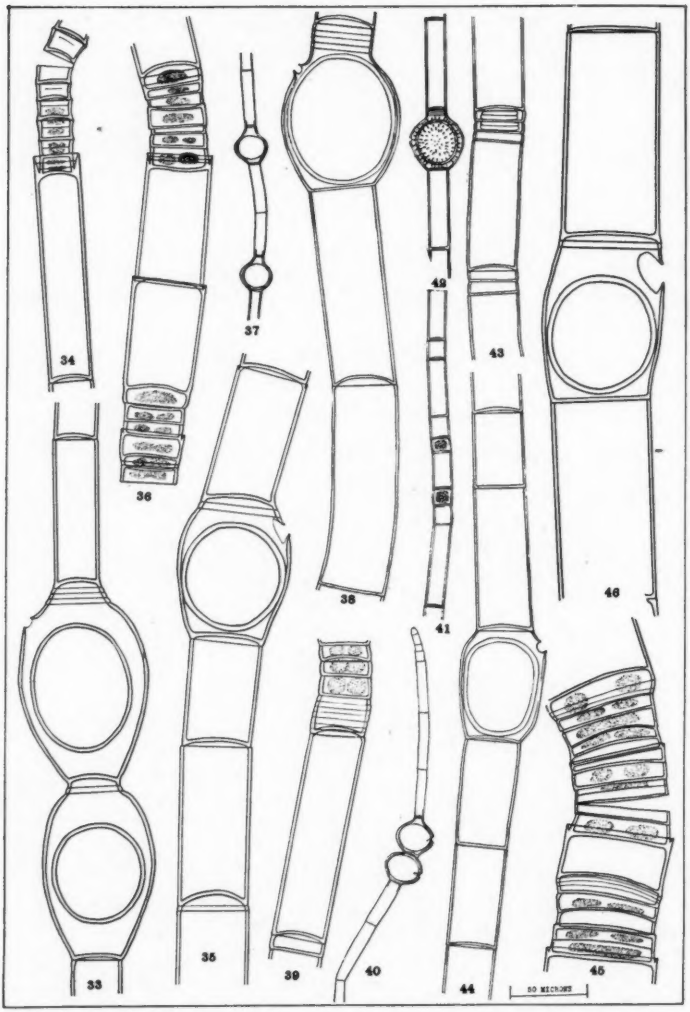

PLATE 3.—Figs. 33, 34. *Oedogonium rivulare* (LeClerc) A. Braun. 35, 36. *O. amplum* Magnus & Wille. 37. *O. rufescens* var. *exiguum* (Elfving) Tiffany. 38, 39. *O. crassum* (Hassall) Wittrock. 40. *O. curvum* Pringsheim. 41, 42. *O. suecicum* Wittrock. 43, 44. *O. capilliforme* Kuetzing. 45, 46. *O. fabulosum* Hirn. (Figs. 33-36, 45, 46 redrawn from Hirn).

x 40-50μ; androsporangium 13-15 x 16-21μ; dwarf male stipe 11-15 x 21-27μ; antheridium 7-10 x 5-7μ.

'Fla." (Collins). Pl. 1, Fig. 4.

9. B. INSIGNIS Pringsheim

Dioecious, nannandrous, gynandrosporous; oogonium ellipsoid, erect or patent, below androsporangium or terminal seta or vegetative cell; oospore ellipsoid with broadly denticulate longitudinal ribs on the outer wall; androsporangia epigynous or scattered, 1-?; dwarf male near or on oogonium; antheridia exterior, 1-3; vegetative cell 19-25 x 48-88μ; oogonium 46-56 x 70-90μ; oospore 44-54 x 68-88μ; androsporangium 16-20 x 9-25μ; dwarf male stipe 16-19 x 29-33μ; antheridium 10-13 x 7-10μ.

"Fla." (Collins). Pl. 1, Fig. 5.

10. B. BULLARDI Transeau and Tiffany

Dioecious, nannandrous, idioandrosporous; oogonium ovoid-ellipsoid or ellipsoid, erect, terminated by long seta, pore evident and supramedian; oospore filling or nearly filling oogonium, ribs of outer wall of oospore dentate, the teeth connected by transverse lines, longitudinal ribs uniting irregularly; androsporangia 1-6; dwarf male slightly surved, on oogonium or suffultory cell or vegetative cell; antheridia exterior, 1-3; vegetative cell 20-32 x 60-165μ; oogonium 56-66 x 70-96μ; oospore 54-64 x 67-94μ; androsporangium 18-21 x 15-33μ; dwarf male stipe 18-21 x 30-33μ; antheridium 9-14 x 6-10μ.

Cypress swamp south of Arcadia. Pl. 1, Figs. 1, 2.

11. B. INTERMEDIA DeBary

Dioecious, nannandrous, gyandrosporus; oogonium subdepressed-globose, patent, below androsporangium; division of suffultory cell nearly median; outer wall of oospore scrobiculate; androsporangia 1 or 2, epigynous or rarely scattered; dwarf male on the oogonium; antheridium interior, stipe slightly curved, shorter than the antheridium; vegetative cell 17-20 x 35-70μ; oogonium 40-48 x 31-40μ; oospore 38-46 x 30-38μ; androsporangium 11-13 x 7-12μ; dwarf male 9-10 x 21-26μ.

Swamp near Frontier; cypress swamp south of Arcalia; roadside south of La Belle; roadside east of Naples; roadside north of Buckingham; cypress swamp south of Arcadia; swamp east of Bayshore. Pl. 2, Fig. 12.

12. B. CONGENER Hirn

Dioecious, nannandrous, idioandrosporous; oogonium depressed-globose or more rarely oboviform-globose, patent, below terminal seta; division of suffultory cell inframedian; outer oospore-wall scrobiculate; androsporangia 1-4; dwarf made a little shorter than the oogonium on which it develops; antheridium interior, stipe about twice as long as the antheridial cell, curved; vegeta-

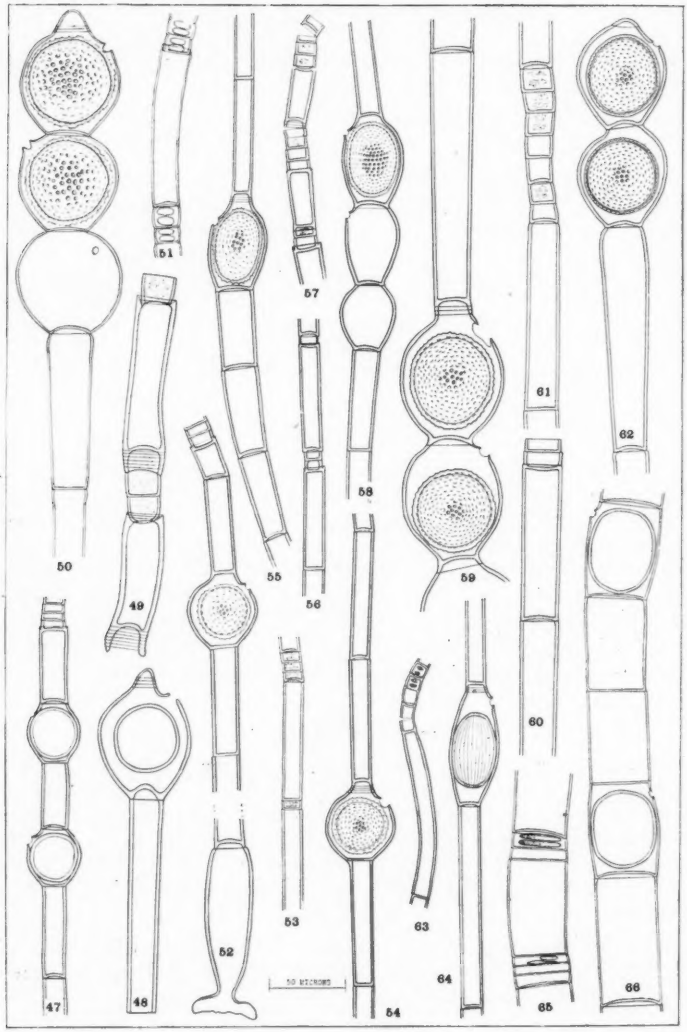

PLATE 4.—Fig. 47. *Oedogonium intermedium* Wittrock. 48, 49. *O. glabrum* Hallas. 50, 51. *O. wyliei* Tiffany. 52. *O. foveolatum* Wittrock. 53, 54. *O. argenteum* Hirn. 55, 56. *O. scrobiculatum* Wittrock. 57, 58. *O. punctatum* Wittrock. 59, 60. *O. taphrosporum* Nordstedt & Hirn. 61, 62. *O. tiffanyi* Ackley. 63, 64. *O. occidentale* (Hirn) Tiffany. 65, 66. *O. capillare* (L.) Kuetzing. (Figs. 48, 49 redrawn from Hallas; Figs. 52, 55-60, 63, 64 from Hirn).

tive cell 19-24 x 40-75μ; oogonium 44-54 x (37-) 40-48μ; oospore 42-52 x 35-46μ; androsporangium 13-15 x 8-13μ; dwarf male 9-13 x 29-34μ; antheridium 10-11 x 14-17μ.

Cypress swamp, south of Arcadia. Pl. 2, Figs. 19, 20.

13. B. SETIGERA (Roth) Ag.

Dioecious, nannandrous, gynandrosporous; oogonium quadrangularly subdepressed- or depressed-globose, patent, generally below terminal seta, more rarely below androsporangium or vegetative cell; division of suffultory cell slightly above median or rarely superior; outer oospore-wall scrobiculate; androsporangia, scattered or more rarely epigynous, 1-3; dwarf male on oogonium or near it; antheridium interior, stipe curved, shorter than antheridium; vegetative cell 25-28 x 62-140μ; oogonium 70-80 x 56-65μ; oospore 67-77 x 53-62μ; androsporangium 16-20 x 10-18μ; dwarf male 11-14 x 30-36μ.

Cypress swamp south of Arcadia.

14. B. ALABAMENSIS Transeau & Brown

Dioecious, nannandrous, gynandrosporous; oogonium globose, depressed-globose, or rarely angularly globose, patent; division of suffultory cell superior; outer spore-wall scrobiculate; androsporangium hypogynous or epigynous or rarely scattered; dwarf male, a little shorter than oogonium, on vegetative cell, antheridium interior, stipe a little curved; vegetative cell 22-40 x 62-111μ; oogonium 77-92μ x 70-88μ; oospore 75-90 x 68-86μ; dwarf male stipe 14-18 x 35-38μ; antheridium 14-15 x 15-16μ.

Cypress swamp south of Arcadia. Pl. 1, Fig. 6.

15. B. POLYANDRIA Cleve

Dioecious, nannandrous, idioandrosporous; oogonium subdepressed-globose, patent, below terminal seta or vegetative cell; division of suffultory cell superior (rarely submedian); outer oospore-wall scrobiculate or nearly smooth; androsporangia to 10-seriate; dwarf male on oogonium, antheridium interior, stipe slightly curved, shorter than antheridium; vegetative cell 15-20 x 45-100μ; oogonium 39-46 x 32-42μ; oospore 37-44 x 30-40μ; androsporangium 12-14 x 11-15μ; dwarf male 8-9 x 23-26μ.

"Fla." (Collins). Pl. 2, Figs. 13, 14.

Oedocladium

One species reported from Florida ..... *O. wettsteinii*

O. WETTSTEINII E. Knapp

Monoecious; oogonium single, generally terminal, globose, apically conic; pore inferior; oospore globose, filling oogonium; outer spore-wall smooth, the middle angulate (in optical section undulate), inner wall smooth; antheridia to

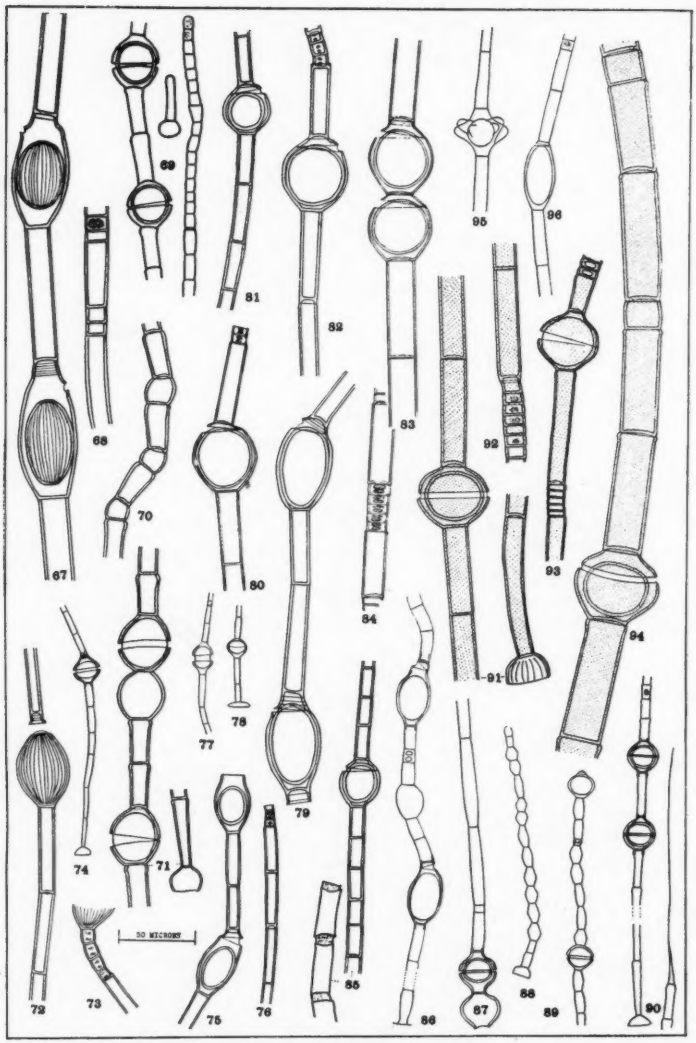

PLATE 5.—Figs. 67, 68. *Oedogonium boscii* (LeClerc) Wittrock. 69. *O. howardii* G. West. 70, 71. *O. latiusculum* Tiffany. 72, 73. *O. pseudacrosporum* Wittrock. 74. *O. tapeinosporum* Wittrock. 75, 76. *O. porrectum* Nordstedt & Hirn. 77. *O. pusillum* Kirchner. 78. *O. inconspicuum* Hirn. 79. *O. ahlstrandii* Wittrock. 80. *O. crispum* (Hassall) Wittrock. 81. *O. crispum* var. *hawaiense* Nordstedt. 82. *O. crispum* f. *inflatum* Hirn.

15-seriate; terminal cell apically conic; vegetative cell subcylindric, the superterraneous 30 x 30-100μ, the subterraneous 4-8 x (up to) 300μ; oogonium 50-60 x 50-63μ; oospore 50-56 x 50-56μ; antheridium 15-20 x 8-20μ.

Sanford, on soil. Pl. 2, Figs. 21-23.

Oedogonium

KEY TO SPECIES

1. Vegetative cell cylindric or capitellate 2
1. Vegetative cell undulate ..... 1. *O. undulatum*
1. Vegetative cell subhexagonal or ellipsoid ..... 2. *O. reinschii*
2. Wall of vegetative cell and oogonium spirally punctate 3
2. Wall of vegetative cell and oogonium not punctate 5
3. Monoecious 4
3. Dioecious, macandrous ..... 3. *O. punctatostriatum*
4. Oogonium 34-46 × 28-42μ ..... 4. *O. minus*
4. Oogonium 49-56 × 40-50μ ..... 5. *O. spirostriatum*
5. Without dwarf males 6
5. With dwarf males 40
6. Oogonium opening by a pore: poriferous 7
6. Oogonium opening by a lid: operculate 27
7. Pore median to supramedian 8
7. Pore superior 11
8. Monoecious ..... 6. *O. curvum*
8. Dioecious, macrandrous 9
9. Oospore-wall smooth 10
9. Oospore-wall echinate ..... 7. *O. suecicum*
10. Oogonium 22-24 × 22-30μ ..... 8. *O. rufescens*
10. Oogonium 26-31 × 29-41μ ..... 9. *O. franklinianum*
10. Oogonium 56-58 × 63-86μ ..... 10. *O. glabrum*
11. Oospore-wall smooth 12
11. Oospore-wall longitudinally costate 21
11. Oospore-wall pitted or scrobiculate 22
12. Monoecious 13
12. Dioecious, macrandrous 14
13. Oogonium 31-37μ in diameter ..... 11. *O. intermedium*
13. Oogonium 70-95μ in diameter ..... 12. *O. kurzii*
14. Oogonium scarcely exceeding vegetative cell in diameter ..... 13. *O. capillare*
14. Oogonium noticeably exceeding vegetative cell in diameter 15
15. Oogonium 36-56μ in diameter 16
15. Oogonium 56-58μ in diameter ..... 10. *O. glabrum*
15. Oogonium 60-96μ in diameter 18
16. Female vegetative cell 20-27μ in diameter 17
16. Female vegetative cell 28-38μ in diameter ..... 14. *O. capilliforme*
17. Oogonium 36-42μ in diameter ..... 15. *O. gracilius*
17. Oogonium 42-49μ in diameter ..... 16. *O. plagiostomum*
18. Vegetative cell 30-54μ in djameter 19
18. Vegetative cell 74-85μ in diameter ..... 17. *O. fabulosum*
19. Division of antheridium horizontal ..... 18. *O. rivulare*

83, 84. *O. pringsheimii* Cramer. 85. *O. abbreviatum* (Hirn) Tiffany. 86. *O. oblongum* Wittrock. 87. *O. gunnii* Wittrock. 88, 89. *O. reinschii* Roy. 90. *O. capitellatum* Wittrock. 91, 92. *O. punctatostriatum* DeBary. 93. *O. minus* Wittrock. 94. *O. spirostriatum* Tiffany. 95. *O. itsigsohnii* DeBary. 96. *O. gracillimum* Wittrock & Lundell. (Figs. 72, 73, 75, 76, 79, 82, 95 redrawn from Hirn).

19. Division of antheridium vertical 20
    20. Diameter of antheridium 28-33μ ..... 19. *O. crassum*
    20. Diameter of antheridium 40-50μ ..... 20. *O. amplum*
21. Oogonium 29-38μ in diameter ..... 21. *O. occidentale*
21. Oogonium 39-51μ in diameter ..... 22. *O. boscii*
    22. Monoecious ..... 23. *O. foveolatum*
    22. Dioecious, macrandrous 23
23. Diameter of oogonium 38-52μ 24
23. Diameter of oogonium 52-64μ ..... 24. *O. wyliei*
23. Diameter of oogonium 64-83μ 26
    24. Suffultory cell enlarged ..... 25. *O. scrobiculatum*
    24. Suffultory cell not enlarged 25
25. Diameter of oogonium 38-45μ ..... 26. *O. punctatum*
25. Diameter of oogonium 44-52μ ..... 27. *O. argenteum*
    26. Length of oogonium 65-69μ ..... 28. *O. tiffanyi*
    26. Length of oogonium 81-113μ ..... 29. *O. taphrosporum*
27. Oogonium with projections ..... 30. *O. itzigsohnii*
27. Oogonium without projections 28
    28. Oospore-wall longitudinally costate ..... 31. *O. pseudacrosporum*
    28. Oospore-wall smooth 29
29. Oospore with a median constriction ..... 32. *O. pusillum*
29. Oospore without a median constriction 30
    30. Division of oogonium median 31
    30. Division of oogonium superior 36
31. Oogonium 13-20μ in diameter 32
31. Oogonium 20-36μ in diameter 33
    32. Division of operculum narrow ..... 33. *O. inconspicuum*
    32. Division of operculum wide ..... 34. *O. tapeinosporum*
33. Monoecious 34
33. Dioecious, macrandrous 35
    34. Vegetative cell cylindric ..... 35. *O. gunnii*
    34. Vegetative cell capitellate ..... 36. *O. capitellatum*
35. Diameter of oogonium 26-33μ ..... 37. *O. howardii*
35. Diameter of oogonium 32-36μ ..... 38. *O. latiusculum*
    36. Monoecious 37
    36. Dioecious, macrandrous 39
37. Oogonium obovoid-globose to subglobose ..... 39. *O. crispum*
37. Oogonium ellipsoid to oblong 38
    38. Diameter of oogonium 14-19μ ..... 40. *O. gracillimum*
    38. Diameter of oogonium 20-26μ ..... 41. *O. oblongum*
    38. Diameter of oogonium 35-42μ ..... 42. *O. ahlstrandii*
39. Diameter of oogonium 24-27μ ..... 43. *O. porrectum*
39. Diameter of oogonium 28-37μ ..... 44. *O. abbreviatum*
39. Diameter of oogonium 35-43μ ..... 45. *O. pringsheimii*
39. Diameter of oogonium 52-60μ ..... 46. *O. iowense*
    40. Oogonium opening by a pore 41
    40. Oogonium opening by a lid 50
41. Pore median or nearly so 42
41. Pore superior 45
    42. Wall of oospore smooth 43
    42. Wall of oospore echinate ..... 47. *O. hystricinum*
    42. Wall of oospore spirally costate 44
43. Oogonium ellipsoid-globose ..... 48. *O. flavescens*
43. Oogonium sexangular-ellipsoid ..... 49. *O. sexangulare*
    44. Suffultory cell enlarged ..... 50. *O. illinoiense*
    44. Suffultory cell not enlarged ..... 51. *O. spirale*
45. Wall of oospore smooth 46
45. Wall of oospore echinate 48
45. Wall of oospore dentate ..... 52. *O. stellatum*
45. Wall of oospore costate 49

46. Suffultory cell enlarged 47
46. Suffultory cell not enlarged ..... 53. *O. irregulare*
47. Oospore 28-29 × 28-29μ ..... 54. *O. silvaticum*
47. Oospore 35-46 × 48-60μ ..... 55. *O. borisianum*
48. Diameter of oogonium 29-38μ ..... 56. *O. armigerum*
48. Diameter of oogonium 63-78μ ..... 57. *O. donnellii*
49. Costae 4-7 in number ..... 52. *O. stellatum*
49. Costae 16-25 in number ..... 58. *O. cyathigerum*
49. Costae 25-35 in number ..... 59. *O. wolleanum*
50. Division of oogonium inframedian 51
50. Division of oogonium median 53
50. Division of oogonium supramedian 57
50. Division of oogonium superior 58
50. Division of oogonium supreme 60
51. Diameter of oogonium 16-20μ ..... 60. *O. circinatum*
51. Diameter of oogonium 20-35μ 52
52. Oogonium with a whorl of projections ..... 61. *O. platygynum*
52. Oogonium without projections ..... 62. *O. contortum*
53. Diameter of oogonium 13-16μ ..... 63. *O. longicolle*
53. Diameter of oogonium 16-21μ ..... 64. *O. senegalense*
53. Diameter of oogonium 20-27μ ..... 65. *O. rothii*
53. Diameter of oogonium 29-39μ 54
53. Diameter of oogonium 53-63μ 56
54. Division of operculum narrow ..... 66. *O. decipiens*
54. Division of operculum wide 55
55. Gyandrosporous only ..... 67. *O. areschougii*
55. Gyandrosporous and idioandrosporous ..... 68. *O. subplenum*
56. Diameter of oospore 42-48μ ..... 69. *O. confertum*
56. Diameter of oospore 48-53μ ..... 70. *O. brasiliense*
57. Oogonium 31-40 × 25-32μ ..... 71. *O. oelandicum*
57. Oogonium 50-55 × 40-44μ ..... 72. *O. costatum*
58. Diameter of oogonium 16-20μ ..... 73. *O. rugulosum*
58. Diameter of oogonium 31-43μ 59
59. Vegetative cell evidently capitellate ..... 74. *O. rigidum*
59. Vegetative cell not capitellate ..... 75. *O. macrandrium*
60. Ooospore-wall longitudinally costate 61
60. Oospore-wall smooth 62
61. Costae 23-30 in number ..... 76. *O. acrosporum*
61. Costae 40-45 in number ..... 77. *O. tentoriale*
62. Diameter of oogonium 36-42μ ..... 78. *O. wabashense*
62. Diameter of oogonium 45-55μ ..... 79. *O. obtruncatum*
62. Diameter of oogonium 55-60μ ..... 80. *O. completum*

1. O. UNDULATUM (Breb.) Al. Braun

Dioecious, nannandrous, gynandrosporous or idioandrosporous; oogonium 1 or 2, subglobose or ellipsoid-globose, operculate, division inferior, wide; oospore globose or subglobose, quite filling oogonium, spore-wall smooth sometimes thick; androsporangia to 7-seriate; vegetative cell undulate (4 undulate constrictions); basal cell elongate, not undulate; terminal cell (sometimes oogonium) apically obtuse; dwarf male elongate-obconic, usually on suffultory cell, rarely on other vegetative cell near oogonium, antheridium interior; vegetative cell 15-22 x 45-110μ; oogonium 48-56 x 50-75μ; oospore 42-50 x 42-52 (-60) μ; androsporangium 15-21 x 7-14μ; dwarf male 8-10 x 48-65 (-70) μ.

Swamp west of West Palm Beach; roadside east of Childs. Pl. 6, Fig. 108.

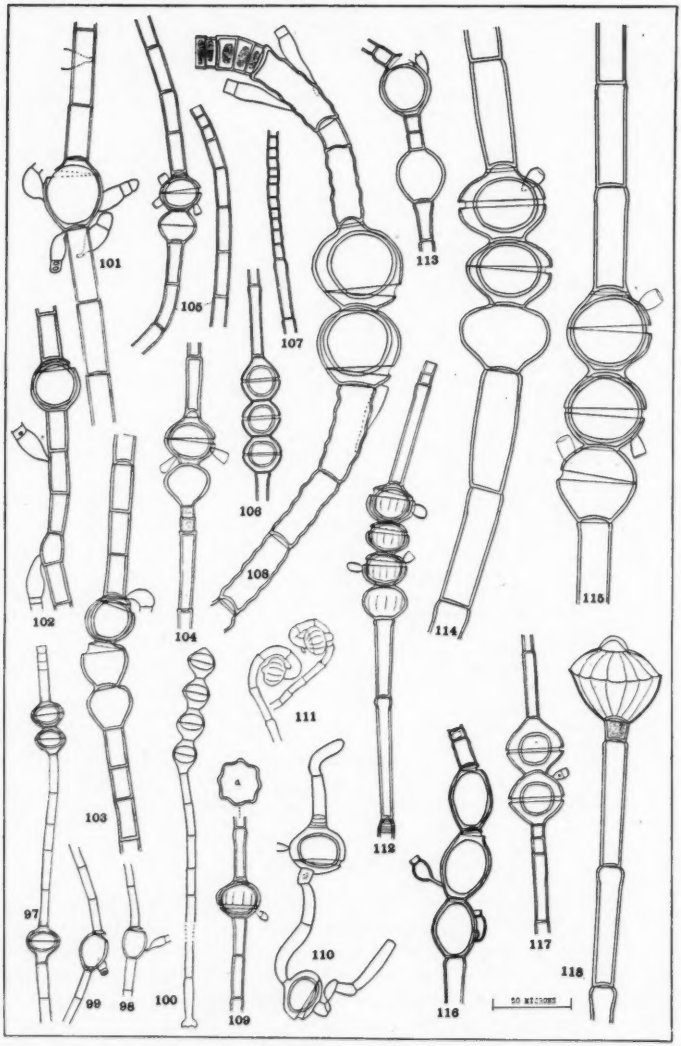

PLATE 6.—Fig. 97. *Oedogonium rothii* (LeClerc) Pringsheim. 98. *O. rugulosum* Nordstedt. 99. *O. rugulosum* var. *rotundatum* (Hirn) Tiffany. 100. *O. senegalense* (Nordstedt) Tiffany. 101. *O. macrandrium* Wittrock. 102. *O. macrandrium* var. *hohenackerii* (Wittrock) Tiffany. 103. *O. macrandrium* f. *lundense* (Wittrock) Hirn. 104. *O. decipiens* Wittrock. 105. *O. decipiens* var. *africanum* Tiffany. 106, 107. *O. sub-*

2. O. REINSCHII Roy

Monoecious; oogonia 1 or 2, globose or depressed-globose or ovoid, rarely terminal, with wide median operculum; oospore similar in shape to oogonium, filling it or not, its wall smooth; antheridium single, subepigynous or subhypogynous; sperms 2, division vertical; vegetative cell often subhexagonal or subellipsoid, sometimes cylindric or subcylindric; basal cell subhemispheric; terminal cell apically obtuse; vegetative cell 5-11 x 9-24μ; oogonium 17-20 x 15-21μ; oospore 13-18 x 14-17μ; antheridium 4-5 x 4-5μ; basal cell 8-16 x 5-10μ.

Cypress swamp and canal south of Arcadia; swamp west of Immokalee; roadside east of Naples; west of Kissimmee; swamp west of West Palm Beach; swamp near Buckingham; cypress swamp east of Ortona; west of Daytona; pond near Longwood. Pl. 5, Figs. 88, 89.

3. O. PUNCTATOSTRIATUM DeBary

Dioecious, macrandrous; oogonium 1, depressed-globose, operculate, division median, rather wide and distinct; oospore depressed-globose, not filling oogonium, spore-wall smooth; antheridium to 10-seriate; sperm 1; wall of vegetative cell and oogonium spirally punctate; basal cell depressed-globose or subhemispheric, wall vertically plicate; female vegetative cell 18-22 x 38-128μ, male 16-19 x 33-108μ; oogonium 48-55 x 38-48μ oospore 40-51 x 35-42μ; antheridium 16-19 x 6-12μ; basal cell 28-31 x 21-25μ.

Cypress swamp south of Arcadia and near La Belle. Pl. 5, Figs. 91, 92.

4. O. MINUS (Wittr.) Wittrock

Monoecious; oogonium 1, pyriform-globose or depressed-globose, operculate, division median, wide; oospore depressed-globose, not filling oogonium, spore-wall smooth; antheridia to 10-seriate, subepigynous or subhypogynous or rarely scattered, cell a little tumid; sperm 1; vegetative cell somewhat capitellate; wall of vegetative cell and of oogonium spirally punctate; basal cell depressed-globose or subhemispheric, wall vertically plicate; vegetative cell 9-13 x 30-78μ; oogonium 34-46 x 28-42μ; oospore 30-42 x 26-36μ; antheridium 9-13 x 3-5μ.

Cypress swamps south of Arcadia and north of Kaller Inn. Pl. 5, Fig. 93.

5. O. SPIROSTRIATUM Tiffany

Monoecious; oogonium single, depressed-globose, with supramedian operculum, wide; oospore depressed-globose, not filling oogonium, wall smooth;

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plenum Tiffany. 108. *O. undulatum* (Brebisson) A. Braun. 109. *O. platygynum* Wittrock. 110. *O. contortum* Hallas. 111. *O. circinatum* Tiffany. 112. *O. oelandicum* Wittrock. 113. *O. rigidum* Hirn. 114. *O. confertum* Hirn. 115. *O. brasiliense* Borge. 116. *O. wabashense* Tiffany. 117. *O. aeroschougii* Wittrock. 118. *O. costatum* Transeau. (Fig. 97 redrawn from Pringsheim; Figs. 103, 108, 113, 115 from Hirn: Fig. 110 from Hallas; Fig. 117 from Wittrock).

antheridium single, alternating with vegetative cell, near oogonium or scattered; sperm single (?); wall of vegetative cell, of oogonium, and of antheridium spirally punctate; basal cell depressed-globose to half round or nearly spheric, vertically plicate; vegetative cell, capitellate, 16-24 x 50-160μ; oogonium 49-56 x 40-50μ; oospore 40-47 x 34-40μ; antheridium 20-23 x 17-20μ; basal cell 27-34 x 22-24μ.

Canal south of Arcadia; roadside east of La Belle; cypress swamps west of Buckingham and south of Arcadia. Pl. 5, Fig. 94.

6. O. CURVUM Pringsheim

Monoecious; oogonia 1-6, depressed-globose, pore median; oospore depressed-globose, filling or not filling oogonium, spore-wall smooth; antheridia hypogynous or epigynous or scattered, 1-7; sperm 1; basal cell elongate; filament usually irregularly curved; vegetative cell 5-10 x 10-40μ; oogonium 21-25 x 18-24μ; oospore 19-23 x 14-19μ; antheridium 6-9 x 6-9μ.

Roadside east of Naples. Pl. 3, Fig. 40.

7. O. SUECICUM Wittrock

Dioecious, macrandrous; oogonium 1, subglobose, pore median; oospore globose, nearly filling oogonium, outer spore-wall echinate, inner smooth; antheridia 2-6; sperm 1; basal cell elongate; terminal cell apically obtuse; vegetative cell 9-14 x 30-90μ; oogonium 32-38 x 34-41μ; oospore 30-37 x 30-37μ; antheridium 10-12 x 13-17μ.

Stream south of Olga. Pl. 3, Figs. 41, 42.

8. O. RUFESCENS Wittrock

Dioecious, macrandrous; oogonia 1-3, obovoid- or depressed-obovoid-globose, pore median, rimiform; oospore globose or depressed-globose, filling oogonium or nearly so, spore-wall smooth; antheridia to 12-seriate; sperm 1; female vegetative cell 8-10 x 34-70μ, male 7-9 x 30-54μ; ogonium 22-24 x 22-30μ; oospore 21-23 x 17-22μ; antheridium 6-8 x 8-12μ.

Roadside east of Naples and east of La Belle; pool south of Denaud; swamp northeast of Bayshore. Pl. 2, Figs. 24-26.

8a. Var. EXIGUUM (Elfving) Tiffany

Vegetative cell a little smaller; oospore subdepressed-globose; antheridia 3; vegetative cell 5-9 x 22-88μ; oogonium 22-24 x 20-28μ; oospore 20-22 x 17-23μ; antheridium 5 x 10-12μ.

Cypress swamp south of La Belle. Pl. 3, Fig. 37.

9. O. FRANKLINIANUM Wittrock

Dioecious, macrandrous; oogonium 1, subglobose, with a supramedian to nearly superior pore; oospore globose, almost filling oogonium, spore-wall

smooth; antheridia 1-4; sperms 2, division horizontal; female vegetative cell 8-12 x 30-95μ, male 8-10 x 25-90μ; oogonium 26-31 x 29-41μ; oospore 24-30 x 24-30μ; antheridium 8-9 x 5-7μ.

Roadside north of Long Key. Pl. 2, Figs. 27, 28.

10. O. GLABRUM Hallas

Dioecious, macrandrous; oogonium 1 (or rarely 2), obovoid, pore superior; oospore globose or subglobose, not filling oogonium, spore-wall smooth; antheridia 5-8; sperms 2, division vertical; terminal cell (sometimes the oogonium) broadly apiculate; female vegetative cell 16-26 x 120-240μ, male 21-25 x 60-150μ; oogonium 56-58 x 63-86μ; oospore 42-49 x 44-63μ; antheridium 20-22 x 7-9μ.

Swamp west of West Palm Beach. Pl. 4, Figs. 48, 49.

11. O. INTERMEDIUM Wittrock

Monoecious; oogonium 1, obovoid to obovoid-globose, pore superior; oospore globose or obovoid-globose, filling oogonium or nearly so, spore-wall smooth and thick; antheridia 1-4, epigynous or subepigynous or hypogynous or rarely scattered; sperms 2; division horizontal; vegetative cell 15-18 x 45-80μ; oogonium 31-37 x 34-45μ; oospore 30-36 x 33-41μ; antheridium 14-16 x 5-10μ.

Stream east of Olga; east of Haines City; swamp east of La Belle. Pl. 4, Fig. 47.

12. O. KURZII Zeller

Monoecious; oogonium 1, rarely in series, obovoid or subellipsoid, pore superior; oospore subglobose or ellipsoid, not filling oogonium, spore-wall smooth; antheridia hypogynous or scattered, to 15-seriate; sperms 2, division vertical; terminal cell apically obtuse; vegetative cell 44-52 x 90-250μ; oogonium 70-95 x 111-130μ; oospore 67-86 x 80-93μ; antheridium 44-52 x 6-16μ.

Creek north of Naples; east of Haines City. Pl. 8, Fig. 143.

13. O. CAPILLARE (L.) Kuetzing

Dioecious, macrandrous; oogonium 1, not or scarcely exceeding the vegetative cell in diameter, cylindric to subcylindric, pore superior; oospore globose to cylindric globose to ovoid, not or completely filling oogonium, spore-wall smooth; antheridia 1-4, often alternating with vegetative cell; sperms 2, division horizontal; basal cell elongate; terminal cell broadly apiculate to obtuse; female vegetative cell 35-56 x 36-120μ, male 35-50 x 35-90μ; oogonium 40-60 x 45-75μ; oospore 30-52 x 35-65μ; antheridium 30-48 x 5-10μ.

Roadside south of Ft. Ogden; creek in Lewiston; cypress swamps west of Moore Haven and east of Orton. Pl. 4, Figs. 65, 66.

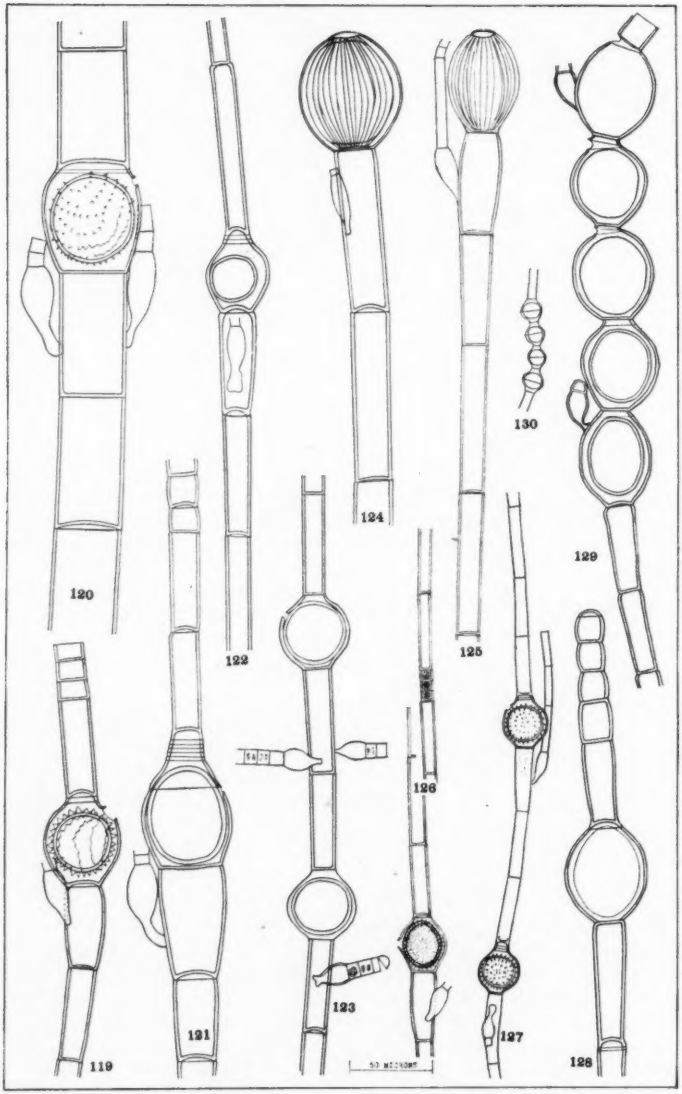

PLATE 7.—Fig. 119. *Oedogonium stellatum* Wittrock. 120. *O. donnellii* Wolle. 121. *O. borisianum* (LeClerc) Wittrock. 122. *O. silvaticum* Hallas. 123. *O. irregulare*

14. O. CAPILLIFORME Kuetzing

Dioecious, macrandrous; oogonium 1, obovoid to subovoid, with superior pore; oospore ovoid-globose, cylindric-globose, subglobose, or globose, not filling oogonium, spore-wall smooth; antheridia 2-8, often alternating with the vegetative cell; sperms 2, division horizontal; basal cell elongate, terminal cell apically obtuse or apiculate; female vegetative cell 28-38 x 42-120μ, male 25-30 x 40-100μ; oogonium 42-50 x 51-62μ; oospore 37-45 x 40-50μ; antheridium 20-25 x 8-10μ.

Ditch west of Daytona Beach. Pl. 3, Figs. 43, 44.

15. O. GRACILIUS (Wittr.) Tiffany

Dioecious, macrandrous; oogonium 1, obovoid-globose, pore superior; oospore globose to subglobose, nearly filling oogonium, spore-wall smooth; basal cell elongate; vegetative cell 20-25 x 40-100μ; oogonium 36-42 x 46-57μ; oospore 34-39 x 36-44μ; antheridium 19-22 x 7-10μ.

Roadside near Ft. Myers and south of Mayaca; ditch west of Daytona Beach; swamp west of West Palm Beach. Pl. 2, Figs. 29, 30.

16. O. PLAGIOSTOMUM Wittrock

Dioecious, macrandrous; oogonium 1, obovoid-globose, with superior pore; oospore globose to subglobose, usually filling oogonium, spore-wall smooth and thick; antheridia 1-6, often alternating with vegetative cell; basal cell elongate; vegetative cell 22-27 x 65-120μ; oogonium 42-49 x 50-60μ; oospore 41-47 x 42-49μ; antheridium 20-24 x 8-10μ.

Cypress swamp south of La Belle; south of Okeechobee. Pl. 2, Figs. 31, 32.

17. O. FABULOSUM Hirn

Dioecious, macrandrous; oogonium 1, slightly tumid, cylindric, pore superior; oospore globose or ellipsoid, not filling oogonium in length, spore-wall smooth; antheridia seriate; sperms 2, division vertical; vegetative cell 74-85 x 115-210μ; oogonium 81-96 x 104-133μ; oospore 75-89 x 78-104μ; antheridium 68-80 x 7-22μ.

Roadside west of Alva. Pl. 3, Figs. 45, 46.

18. O. RIVULARE Al. Braun

Dioecious, macrandrous; oogonia 1-7, obovoid, pore superior; oospore obovoid, ellipsoid, or subglobose, not filling oogonium longitudinally, spore-wall smooth; antheridia to 13-seriate; sperms 2, division horizontal; basal cell elongate; female vegetative cell 35-45 x 110-350μ, male 30-36 x 120-280μ; oogonium 70-85 x 130-160μ; oospore 55-70 x 65-100μ; antheridium 21-28 x 14-26μ.

"Fla." (Collins). Pl. 3, Figs. 33, 34.

Wittrock. 124. *O. tentoriale* Nordstedt & Hirn. 125. *O. acrosporum* DeBary. 126. *O. hystricinum* Transeau & Tiffany. 127. *O. armigerum* Hirn. 128. *O. completum* (Hirn) Tiffany. 129. *O. obtruncatum* Wittrock. 130. *O. longicolle* Nordstedt. (Figs. 119, 120 redrawn from Hirn; Fig. 122 from Hallas; Fig. 130 from Nordstedt).

19. O. CRASSUM (Hass.) Wittrock

Dioecious, macrandrous; oogonia 1 or 2, ovoid to obovoid-ellipsoid, pore superior; oospore variable, ellipsoid to globose, filling or not filling oogonium, spore-wall smooth; antheridia 2-25; sperms 2, division vertical; female vegetative cell 30-50 x 72-340μ, male 24-36 x 72-260μ; oogonium 60-80 x 75-120μ; oospore 58-76 x 65-96μ; antheridium 28-33 x 8-20μ.

Roadside east of Childs, north of Wauchula, east of Orton, and south of Mayaca; ditch south of Ft. Myers; stream south of Olga; cypress swamp south of Arcadia; swamps near La Belle and west of Moore Haven. Pl. 3, Figs. 38, 39.

20. O. AMPLUM Magnus & Wille

Dioecious, macrandrous; oogonia 1 or 2, ovoid to obovoid-ellipsoid, pore superior; oospore ellipsoid to broadly ellipsoid (or nearly globose), nearly filling oogonium, its wall smooth; antheridia 2-20, division vertical; female vegetative cell 46-54 x 70-160μ, male 42-50 x 65-200μ; oogonium 75-90 x 83-115μ; oospore 72-85 x 77-100μ; antheridium 40-50 x 8-20μ.

Ditch south of Ft. Myers; roadside north of Olga. Pl. 3, Figs. 35, 36.

21. O. OCCIDENTALE (Hirn) Tiffany

Dioecious, macrandrous; oogonium single, oblong-ellipsoid, pore superior; oospore ellipsoid, not nearly filling oogonium longitudinally, its wall of three layers: the outer and middle with 27-35 continuous longitudinal costae, the inner smooth; antheridia 1-6, scattered; sperms 2, division horizontal; vegetative cell 8-16 x 50-165μ; oogonium 29-38 x 69-100μ; oospore 27-37 x 42-50μ; antheridium 12-13 x 10-16μ.

Pool south of Jacksonville. Pl. 4, Figs. 63, 64.

22. O. BOSCII Wittrock

Dioecious, macrandrous; oogonium 1 (rarely 2), oblong-ellipsoid, pore superior; oospore ellipsoid, not nearly filling oogonium longitudinally, spore-wall of three layers: outer and middle layers with 27-35 continuous, rarely anastomosing, longitudinal ribs, inner smooth; antheridia 1-8, scattered, often in upper part of filament; sperms 2, division vertical; female vegetative cell 14-23 x 45-135μ, male 13-18 x 52-108μ; oogonium 39-51 x 75-110μ; oospore 36-43 x 56-70μ; antheridium 13-14 x 6-16μ.

Cypress swamps south of Arcadia, west of Moore Haven, and northeast of Bayshore. Pl. 5, Figs. 67, 68.

23. O. FOVEOLATUM Wittrock

Monoecious; oogonia 1 or 2, obovoid to subellipsoid-globose, with superior pore; oospore globose to subellipsoid-globose, filling or not filling oogonium, outer spore-wall scrobiculate; antheridia 1-7; sperms 2, division horizontal; basal cell elongate; terminal cell apically obtuse; vegetative cell 14-23 x 35-

115μ; oogonium 37-49 x 38-61μ; oospore 33-46 x 34-53μ; antheridium 12-19 x 5-12μ.

Roadside north of Long Key. Pl. 4, Fig. 52.

24. O. WYLIEI Tiffany

Dioecious, macrandrous; oogonia 1-4, globose to ovoid, pore superior; oospore globose to ovoid, filling or not filling oogonium, outer spore-wall irregularly scrobiculate; antheridia 1-4; sperms 2, division horizontal; basal cell elongate; terminal cell, often an oogonium, apically obtuse or broadly apiculate; vegetative cell 16-24 x 80-170μ; oogonium 52-64 x 68-112μ; oospore 48-60 x 52-64μ; antheridium 16-19 x 8-18μ.

Cypress swamp south of Arcadia. Pl. 4, Figs. 50, 51.

25. O. SCROBICULATUM Wittrock

Dioecious, macrandrous; oogonia 1-3, obovoid or subellipsoid, pore superior; oospore of same form as oogonium and nearly filling it, outer spore-wall scrobiculate, inner smooth; antheridium 1-?; sperms 2, division horizontal; female vegetative cell 16-24 x 50-144μ, male 15- 19 x 45-110μ; suffultory cell 21-30 x 34-90μ; oogonium 40-48 x 60-88μ; oospore 39-45 x 48-57μ; antheridium 13-15 x 8-12μ.

Roadside north of Long Key. Pl. 4, Figs. 55, 56.

26. O. PUNCTATUM Wittrock

Dioecious, macrandrous; oogonia 1-4, obovoid (rarely globose-obovoid), pore superior; oospore obovoid, nearly filling oogonium (rarely subglobose and not filling oogonium), outer spore-wall scrobiculate; antheridia 1-5, often alternating with vegetative cell; sperms 2, division horizontal; basal cell elongate; terminal cell (often oogonium) apically obtuse; vegetative cell 15-22 x 42-128μ; oogonium 38-45 (-48) x 52-65μ; oospore 37-43 x 43-55μ; antheridium 15-17 x 6-10μ.

Roadside north of Long Key. Pl. 4, Figs. 57, 58.

27. O. ARGENTEUM Hirn

Dioecious, macrandrous; oogonium 1, obovoid-globose to globose, pore superior (rarely supramedian); oospore ovoid to globose, outer layer of spore-wall scrobiculate; antheridia 3-4; sperms 2, division horizontal; basal cell elongate; female vegetative cell (14-) 20-28 x 80-160μ, male 20-22 x 70-160μ; oogonium 44-52 x 48-62μ; oospore 43-48 x 44-50μ; antheridium 22 x 8μ.

Roadside east of Naples. Pl. 4, Figs. 53, 54.

28. O. TIFFANYI Ackley

Dioecious, macrandrous; oogonia 1 or 2, subdepressed- globose or broadly pyriform-globose, pore superior; oospore globose, nearly filling ogonium,

median layer of spore-wall scrobiculate; suffultory cell enlarged; antheridia 1-7; sperms 2, division horizontal; basal cell ellipsoid-elongate; vegetative cell (15-) 21-25 x 100-240μ; suffultory cell 25-32 x 100-230μ; oogonium 64-76 x 65-69μ; oospore 54-65 x 55-66μ; antheridium 19-21 x 14-20μ.

Cypress swamp east of Ortona. Pl. 4, Figs. 61, 62.

29. O. TAPHROSPORUM Nordstedt & Hirn

Dioecious, macrandrous; oogonia 1-6, obovoid or obovoid-ellipsoid, pore superior; oospore globose or ellipsoid-globose, not filling oogonium, outer layer of spore-wall scrobiculate, inner layer smooth; antheridia 2-?; terminal cell, sometimes an oogonium, obtuse; basal cell elongate; vegetative cell 25-38 x 100-375μ; oogonium 70-83 x 81-113μ; oospore 58-65 x 62-70μ; antheridium 24-32 x 8-12μ.

Cypress swamp south of Arcadia. Pl. 4, Figs. 59, 60.

30. O. ITZIGSOHNII DeBary

Monoecious; oogonium 1, ellipsoid, with median, conically obtuse projections appearing stellate in vertical view, with 7-10 radiations, operculate, division infra-median; oospore globose, not completely filling oogonium, spore-wall smooth; antheridia 1 or 2; terminal cell apically obtuse or apiculate; vegetative cell 8-10 x 25-60μ; oogonium 34-40 x 32-40μ; oospore 20-23 x 20-23μ; antheridium 8-9 x 8-15μ.

Swamp near Buckingham. Pl. 5, Fig. 95.

31. O. PSEUDACROSPORUM Wittrock

Monoecious; oogonium 1, ellipsoid, operculate, division supreme, lid very small and often deciduous; oospore ellipsoid, completely filling oogonium, spore-wall coalescing with that of oogonium, longitudinally ribbed, ribs evidently crenulate; antheridia 1-4, hypogynous or subepigynous; sperms 2, division horizontal; basal cell elongate; terminal cell long, setiform; vegetative cell 9-13 x 32-110μ; oogonium (27-) 32-37 x 44-56μ; antheridium 8-13 x 6-12μ.

Canal south of Arcadia. Pl. 5, Figs. 72, 73.

32. O. PUSILLUM Kirchner

Monoecious; oogonium 1 (rarely 2), subbiconic-ellipsoid or subbiconic-globose, seen from above circular, margin even, operculate, division wide (up to 2.5 μ); oospore ellipsoid or globose, generally constricted at the middle, not quite filling oogonium, spore-wall smooth; antheridia 1 or 2, subepigynous, sperm 1 (?); basal cell subhemispheric; terminal cell obtuse or obtusely conic; vegetative cell 3-6 x 10-60 μ; oogonium 14-16 x 15-25μ; oospore 11-13 x 13-15μ; antheridium 3-4 x 5-6μ; basal cell 7-8 x 7-8μ.

Cypress swamp south of Arcadia. Pl. 5, Fig. 77.

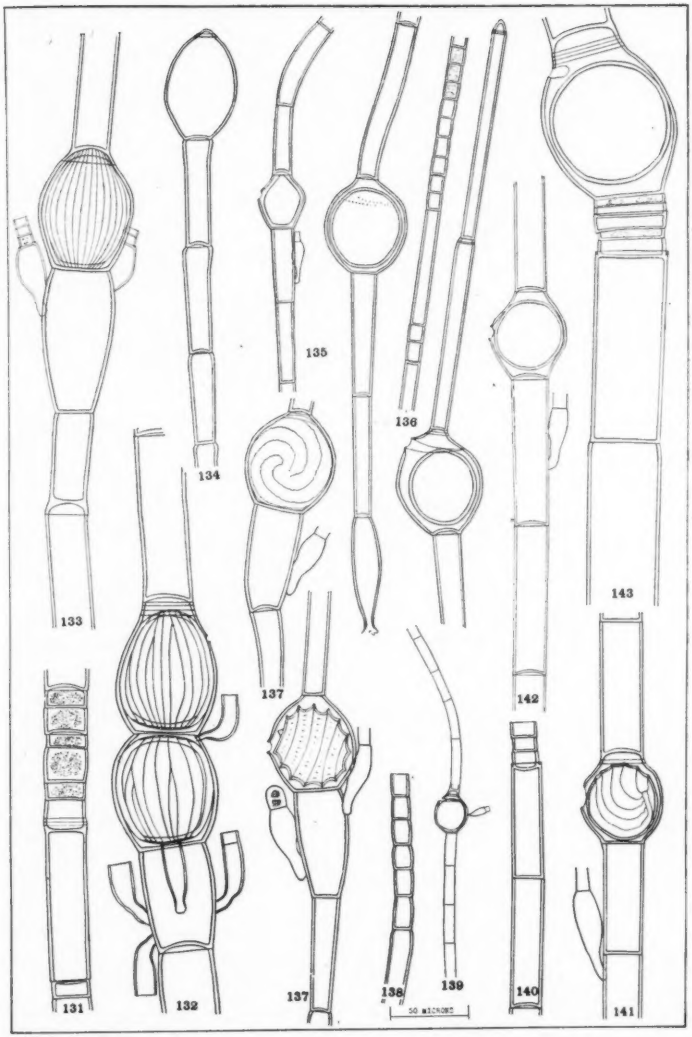

PLATE 8.—Figs. 131, 132. *Oedogonium cyathigerum* Wittrock. 133. *O. wolleanum* Wittrock. 134. *O. obtruncatum* var. *ellipsoideum* Wittrock. 135. *O. sexangulare* Cleve. 136. *O. iowense* Tiffany. 137, 138. *O. illinoiense* Transeau. 139. *O. rugulosum* var. *rotundatum* (Hirn) Tiffany. 140, 141. *O. spirale* Hirn. 142. *O. flavescens* (Hassall) Wittrock. 143. *O. kurzii* Zeller. (Figs. 133, 134, 140, 141, 143 redrawn from Hirn).

33. O. INCONSPICUUM Hirn

(Dioecious, macrandrous?); oogonia 1-4, depressed- or subpyriform-globose, operculate, division median, narrow; oospore depressed-globose (rarely ovoid), filling the inflated part of oogonium, spore-wall smooth; vegetative cell 3-5 x 20-34μ; oogonium 13-18 x (13-) 17-23μ; oospore 12-17 x 8-12μ; basal cell 10-18 x 4-8μ.

Roadside east of Naples; cypress swamps south of Arcadia and near Buckingham. Pl. 5, Fig. 78.

34. O. TAPEINOSPORUM Wittrock

Oogonia 1 or 2, depressed-globose, operculate, division median, wide; oospore depressed-globose, not (rarely nearly) filling oogonium, spore-wall smooth; basal cell subhemispheric; terminal cell obtuse; vegetative cell (2-) 3-5 x 10-40μ; oogonium 14-19 x (14-) 17-23μ; oospore 13-16 x 8-14μ; basal cell 8-14 x 5-7μ.

Pool east of Alva and south of Okeechobee; roadside east of Naples; swamp west of Immokalee. Pl. 5, Fig. 74.

35. O. GUNNII Wittrock

Monoecious; oogonia 1-4, subdepressed- or depressed-globose, operculate, division median, narrow but distinct; oospore same form as oogonium and filling it, spore-wall smooth, outer layer thick and hyaline, inner brown; antheridium subepigynous; vegetative cell 6-9 x 30-85μ; oogonium 23-29 x 19-29; oospore 22-27 x 17-23μ; antheridium 6 x 12μ.

West of Daytona Beach. Pl. 5, Fig. 87.

36. O. CAPITELLATUM Wittrock

Monoecious; oogonium 1, subdepressed- or depressed-globose, operculate, division median, narrow but distinct; oospore depressed-globose, completing (or nearly so) oogonium, spore-wall smooth; antheridia 1-2, subepigynous or hypogynous or rarely scattered; sperm 1 (?); vegetative cell capitellate; basal cell subhemispheric; terminal cell piliform; vegetative cell 6-9 x 20-60μ; oogonium 20-26 x 17-23μ; oospore 18-23 x 15-19μ; antheridium 6-7 x 8-9μ; basal cell 16-18 x 6-8μ.

Roadside south of La Belle and west of Daytona; swamp west of Immokalee. Pl. 5, Fig. 90.

37. O. HOWARDII G. West

Dioecious, macrandrous; oogonia 1 or 2, globose or subglobose with broad median operculum; oospore globose filling oogonium, its wall smooth; antheridia to 16-seriate; sperm 1; vegetative cell broadly capitellate; basal cell subhemispheric to nearly spheric; vegetative cell 7-12 x 18-42μ; oogonium 26-33 x (23-) 26-33μ; oospore 21-30 x 24-30μ; antheridium 7-9 x 5-14μ; basal cell 12-20 x 10-13μ.

Roadside east of Naples and south of Okeechobee; pond, junction of Highways 2 and 25. Pl. 5, Fig. 69.

38. O. LATIUSCULUM Tiffany

Dioecious, macrandrous; oogonia 1 or 2, globose to ellipsoid-globose, operculate, division median, very wide; oospore of the same form as the oogonium which it very nearly or completely fills, wall smooth; male plant somewhat larger than the female; antheridium 1, usually alternating with a single vegetative cell, sperm 1; vegetative cell distinctly capitellate; basal cell of filament subhemispheric; filament not infrequently incrusted with lime; female vegetative cell 10-18 x 16-40μ, male 14-20 x 16-40μ; oogonium 32-36 x 32-40μ; oospore 28-32 x 28-34μ; antheridium 14-18 x 12-20μ; basal cell 16-24 x 12-16μ.

Pool east of Alva; roadside north of Long Key. Pl. 5, Figs. 70, 71.

39. O. CRISPUM (Hass.) Wittrock

Monoecious; oogonium usually 1, obovoid-globose, operculate, division superior; oospore globose or subglobose, quite filling the oogonium, spore-wall smooth; antheridia 1-5, subepigynous or hypogynous; sperms 2, division horizontal; basal cell elongate; terminal cell apically obtuse; vegetative cell (10-) 12-16 x 35-80μ; oogonium 37-45 x 41-53μ; oospore 35-43 x 37-43μ; antheridium 8-14 x 7-12μ.

West of Okeechobee. Pl. 5, Fig. 80.

39a. Var. HAWAIENSE Nordstedt

Oogonium subovoid-globose to pyriform-globose, not filled by oospore; terminal cell mucronate or shortly setigerous; vegetative cell 10-16 x 20-64μ; oogonium 30-38 x 31-38μ; oospore 27-32 x 27-33μ; antheridium 8-11 x 6-8μ.

Swamp south of La Bell; cypress swamp south of Arcadia. Pl. 5, Fig. 81.

39b. F. INFLATUM Hirn

Oogonium obovoid-globose; vegetative cell 12-16 x 35-95μ; oogonium 40-50 x 45-53μ; oospore 37-45 x 38-45μ; antheridium 8-12 x 9-12μ.

Swamp south of Arcadia. Pl. 5, Fig. 82.

40. O. GRACILLIMUM Wittrock & Lundell

Monoecious; oogonium 1, oblong, operculate, division superior; oospore oblong-ellipsoid, not filling oognium, spore-wall smooth; antheridium 1; sperms 2, division horizontal; basal cell elongate vegetative cell 4-7 x 16-42μ; oogonium 14-19 x 34-40μ; oospore 13-17 x 24-32μ; antheridium 3-5 x 4-7μ.

Canal west of Everglades; cypress swamps south of La Belle, east of Ortona, and west of West Palm Beach; cut-off near Ft. Myers; south of Okeechobee. Pl. 5, Fig. 96.

41. O. OBLONGUM Wittrock

Monoecious; oogonium 1, oblong, operculate, division superior; oospore ellipsoid to ovoid, not filling oogonium longitudinally, spore-wall smooth; antheridia 1-3; sperms 2, division horizontal; basal cell elongate; vegetative cell 6-11 x 20-86μ; oogonium 20-26 x 41-60μ; oospore 19-23 x 30-36μ; antheridium 6-9 x 7-9μ.

Canal west of Everglades. Pl. 5, Fig. 86.

42. O. AHLSTRANDII Wittrock

Monoecious; oogonium 1, ellipsoid, operculate, division superior; oospore ellipsoid, filling oogonium, wall smooth; antheridia 1 or 2, hypogynous; sperms 2, division horizontal; terminal cell apically obtuse; vegetative cell 10-18 x 30-180μ; oogonium 35-42 x 57-69μ; oospore 34-41 x 53-62μ; antheridium 13-17 x 9-12μ.

Pond near Jacksonville. Pl. 5, Fig. 79.

43. O. PORRECTUM Nordstedi & Hirn

Dioecious, macrandrous; oogonium 1, oblong, operculate, division superior; oospore ellipsoid or globose-ellipsoid, not filling oogonium longitudinally, spore-wall smooth; antheridia to 4-seriate; sperms 2, division horizontal; female vegetative cell 7-10 x 25-55μ, male 6-9 x 25-62μ; oogonium 24-27 x 44-53μ; oospore 23-24 x 25-28μ; antheridium 6-7 x 6-8μ.

Cypress swamp south of Arcadia. Pl. 5, Figs. 75-76.

44. O. ABBREVIATUM (Hirn) Tiffany

Dioecious, macrandrous; oogonia 1-3, obovoid-globose to depressed-globose, operculate, division superior; oospore similar to oogonium in shape, its wall smooth; antheridia 1-6, often alternating with vegetative cell; sperms 2, division horizontal; basal cell elongate; upper cells of filament usually shorter than the lower ones; vegetative cell 10-22 x 15-50μ; oogonium 28-37 x 26-38μ; oospore 26-34 x 24-35μ; antheridium 9-16 x 5-10μ.

Swamp near Frontier. Pl. 5, Fig. 85.

45. O. PRINGSHEIMII Cramer

Dioecious, macrandrous; oogonia 1-6, subovoid-globose, operculate, division superior; oospore globose, nearly filling oogonium, spore-wall smooth, often thick; antheridia to 10-seriate, often alternating with vegetative cell; sperms 2, division horizontal; basal cell elongate; terminal cell broadly apiculate or obtuse; female vegetative cell 14-20 x 28-100μ, male 12-16 x 24-64μ; oogonium 35-43 x 36-46μ; oospore 30-37 x 30-37μ; antheridium 10-15 x 6-9μ.

Swamp near Frontier. Pl. 5, Figs. 83, 84.

46. O. IOWENSE Tiffany

Dioecious, macrandrous; oogonia 1 or 2, globose or ellipsoid-globose, operculate, division superior; oospore of the same form as the oogonium, which it

completely fills or not, spore-wall smooth; antheridia 1-25; sperms 2, division horizontal; basal cell of filament commonly elongate; vegetative cell 10-16 x 44-100μ; oogonium 52-60 x 60-80μ; oospore 45-56 x 50-64μ; antheridium 10-12 x 10-20μ; basal cell 16-24 x 60-80μ.

Pond south of Sarasota. Pl. 8, Fig. 136.

47. O. HYSTRICINUM Transeau & Tiffany

Dioecious, nannandrous, idioandrosporous; oogonium 1, globose or somewhat obovoid, pore median; oospore globose to subglobose, nearly filling the oogonium, outer spore-wall densely covered with spines; suffultory cell swollen; androsporangia 3-6; terminal cell obtuse; basal cell elongate; dwarf male nearly straight, resting on the suffultory cell, antheridium exterior, 1; vegetative cell of oogonial plants 8-15 x 42-100μ, androsporangial 6-9 x 50-67; suffultory cell 16-19 x 42-70μ; oogonium 30-40 x 36-53; oospore (including spines) 23-38 x 28-43μ; androsporangium 6-8 x 8-15μ; dwarf male stipe 6-10 x 20-32μ; antheridium 5-6 x 6-10μ.

Cypress swamp near La Belle; stream east of Olga; creek south of Ft. Myers; swamp near Frontier. Pl. 7, Fig. 126.

48. O. FLAVESCENS Wittrock

Dioecious, nannandrous, idioandrosporous or gynandrosporous; oogonium 1, ellipsoid-globose to subglobose, pore median; oospore globose, not quite filling oogonium, spore-wall smooth; androsporangia 1-9; dwarf male somewhat curved, on the suffultory cell; antheridia 1-2; vegetative cell 18-23 x 72-140μ; oogonium 49-52 x 51-60μ; oospore 45-49 x 45-49μ; androsporangium 17-20 x 8-18μ; dwarf male stipe 11-12 x 36-45μ; antheridium 9-10 x 15-20μ.

Swamp east of La Belle. Pl. 8, Fig. 142.

49. O. SEXANGULARE Cleve

Dioecious, nannandrous, gynandrosporous; oogonium 1 (rarely 2), sexangular-ellipsoid, pore a little above median; oospore same form as oogonium and nearly filling it, spore-wall smooth; suffultory cell sometimes slightly tumid; androsporangia 1-3; dwarf male on suffultory cell, a little curved, stipe of 2-3 cells; antheridium exterior, 1; vegetative cell 9-16 x 30-110μ; oogonium 29-33 x 33-39μ; oospore 27-31 x 31-36μ; androsporangium 13-14 x 10-14μ; dwarf male stipe 7-9 x 21-30μ; antheridium 6-7 x 9-12μ.

Cypress swamps south of La Belle and south of Arcadia; roadside east of Naples; swamp north of Kaller Inn. Pl. 8, Fig. 135.

50. O. ILLINOIENSE Transeau

Dioecious, nannandrous, gynandrosporous; oogonium 1, subglobose to obovoid-globose, pore median; oospore globose or subglobose, nearly filling oogonium, outer spore-wall with 4-7 spiral ribs, uniting at poles, polar axis always

transverse to axis of filament; suffultory cell enlarged; androsporangia 1-5; basal cell elongate; dwarf male slightly curved, on suffultory cell; antheridia exterior, 1-4; vegetative cell 13-18 x 80-140μ; suffultory cell 32-40 x 50-80μ; oogonium 51-60 x 60-70μ; oospore 45-56 x 48-66μ; androsporangium 13-17 x 17-22μ; dwarf male stipe 14-17 x 37-57μ; antheridium 9-12 x 15-23μ.

Swamp east of Bayshore. Pl. 8, Figs. 137, 138.

51. O. SPIRALE Hirn

Dioecious, nannandrous, idioandrosporous; oogonium 1, subglobose or obovoid-globose, pore median; oospore globose or subglobose, not filling oogonium, spore-wall double: outer layer with 4-7 spiral ribs, anastomosing, united at the poles, inner layer smooth; androsporangia 1-3; basal cell elongate; dwarf male a little curved, near oogonium; antheridium exterior, 1; vegetative cell 20-33 x 40-130μ; oogonium 52-60 x 52-60μ; oospore 46-56 x 46-56μ; androsporangium 17-22 x 11-14μ; dwarf male stipe 11-16 x 41-59μ; antheridium 10-11 x 18-20μ.

Pond south of Sarasota. Pl. 8, Figs. 140, 141.

52. O. STELLATUM Wittrock

Dioecious, nannandrous, gynandrosporous; oogonia 1-3, obovoid-globose, pore superior; oospore globose, quite filling oogonium, outer spore-wall with 4-7 somewhat spirally arranged ribs, appearing definitely dentate on the margin, sometimes anastomosing; androsporangia 1-3, usually subepigynous; basal cell elongate; terminal cell slender, subhyaline, apically obtuse; dwarf male suberect, on suffultory cell; antheridia 1 or 2; vegetative cell 15-35 x 40-225μ; oogonium 51-64 x 56-70μ; oospore (with ribs) 50-58 x 50-58μ; androsporangium 14-19 x 13-20μ; dwarf male stipe 11-13 x 45-52μ; antheridium 6-9 x 8-13μ.

"Fla." (Collins). Pl. 7, Fig. 119.

53. O. IRREGULARE Wittrock

Dioecious, nannandrous; oogonium 1, globose or rarely subdepressed-globose, pore superior; oospore globose, completely filling oogonium, spore-wall smooth; dwarf male erect, on or near oogonium; antheridia exterior, 1-4; vegetative cell 15-20 x 40-80μ; oogonium 37-45 x 36-47μ; oospore 36-42 x 34-41μ; dwarf male stipe 12-15 x 20-24μ; antheridium 10-12 x 6-8μ.

"Fla." (Collins). Pl. 7, Fig. 123.

54. O. SILVATICUM Hallas

Dioecious, nannandrous, gynandrosporous; oogonium 1, ellipsoid-globose, pore superior; oospore globose, not filling oogonium, its wall smooth; suffultory cell subtumid; dwarf male suberect, on suffultory cell; antheridium exter-

ior; vegetative cell 12-15 x 65-120μ; suffultory cell 20 x 60μ; oogonium 37 x 50μ; oospore 28-29 x 28-29μ; androsporangium 7 x 17μ; dwarf male stipe 11 x 39μ; antheridium 7 x 7μ.

Roadside west of Daytona Beach. Pl. 7, Fig. 122.

55. O. BORISIANUM (Le Cl.) Wittrock

Dioecious, nannandrous, gynandrosporous or idioandrosporous; oogonia 1-5, obovoid or quadrangular-ellipsoid, pore superior; oospore ovoid to obovoid (often quadrangular-ovoid), not filling oogonium, spore-wall smooth; androsporangia 1-7, usually in the upper part of the filament; basal cell elongate; terminal cell often an oogonium, broadly apiculate, obtuse, or sometimes setiferous; suffultory cell swollen; dwarf male, somewhat curved, on suffultory cell; antheridia 2; vegetative cell, sometimes capitellate, 15-23 x 45-140μ; suffultory cell 31-38 x 50-92μ; oogonium (33-) 40-50 x 55-90μ; oospore 35-46 x 48-60μ; androsporangium 16-19 x 15-23μ; dwarf male stipe 12-18 x 35-47μ; antheridium 7-10 x 11-16μ.

Swamp west of West Palm Beach; roadside east and west of Okeechobee; ditch south of Ft. Myers. Pl. 7, Fig. 121.

56. O. ARMIGERUM Hirn

Dioecious, nannandrous; oogonium 1, subglobose, pore superior; oospore globose, nearly filling oogonium, outer layer of spore-wall echinate; dwarf male curved, on suffultory cell, stipe sometimes 2-4 celled; antheridia exterior, 1 or 2; suffultory cell sometimes tumid; vegetative cell 9-13 x 36-100μ; oogonium 29-38 x 30-40μ; oospore 26-30 x 26-29μ dwarf male, lower cell 7-8 x 20-24μ, upper cell 4-6 x 21-30μ; antheridium 5-6 x 7-8μ; basal cell 9-10 x 45-47μ.

Cypress swamp south of Arcadia; ditch west of Clewiston; roadside near Ft. Myers; creek north of Naples; swamps near La Belle, northeast of Bayshore, and west of West Palm Beach. Pl. 7, Fig. 127.

57. O. DONNELLII Wolle

Dioecious, nannandrous, idioandrosporous; oogonium 1 (rarely 2), obovoid-globose, pore superior; oospore globose, not filling oogonium, outer layer of spore-wall echinate, spines spirally arranged, spirals 5-7, anastomosing; androsporangia 4-10; dwarf male a little curved, on suffultory cell or rarely on oogonium; antheridia exterior, 1 or 2-?; vegetative cell 41-59 x 54-175μ; oogonium 63-78 x 70-93μ; oospore (with spines) 60-70 x 60-70μ; androsporangium 40-45 x 10-12μ; dwarf male stipe 16-21 x 63-74μ; antheridium 14-15 x 8-22μ.

"Fla." (Collins). Pl. 7, Fig.120.

58. O. CYATHIGERUM Wittrock

Dioecious, nannandrous, idioandrosporous; oogonia 1-3, subovoid or quadrangular-ellipsoid, pore superior; oospore same form as oogonium, filling it

outer layer of spore-wall smooth, the median with 16-25 longitudinal, continuous, rarely anastomosing, often curved, ridges — the inner smooth; basal cell elongate; terminal cell, often an oogonium, obtuse; dwarf male goblet-shaped, curved, on the suffultory cell or oogonium; antheridium interior; vegetative cell 21-30 x 40-300μ; suffultory cell 42-48 x 75-110μ; oogonium 57-66 x 70-100μ; oospore 51-62 x 60-75μ; androsporangium 23-30 x 12-30μ; dwarf male cell 12-15 x 50-58μ.

Cypress swamps south of Arcadia, south of La Belle, and east of Ortona; roadside south of Mayaca and south of Okeechobee; swamps west of Moore Haven and west of West Palm Beach. Pl. 8, Figs. 131, 132.

59. O. WOLLEANUM Wittrock

Dioecious, nannandrous, gynandrosporous or idioandrosporous; oogonia 1-4, subobovoid or quadrangular-ellipsoid, pore superior, wall with raised longitudinal lines on the inner surface; oospore of same form as oogonium, quite filling it, outer layer of spore-wall with 25-35 entire longitudinal ribs, rarely anastomosing, inner layer smooth; androsporangia 1-3, often subepigynous or scattered in the upper part of the filament; basal cell elongate; terminal cell, sometimes an oogonium, short-acute or acuminate; dwarf male on suffultory cell, stipe slightly curved; antheridia exterior, 1-3; vegetative cell 21-30 x 65-235μ; suffultory cell 45-56 x 68-110μ; oogonium 58-68 x 69-89μ; oospore 56-66 x 65-83μ; androsporangium 21-30 x 18-25μ; dwarf male stipe 15-24 x 54-60μ; antheridium 9-14 x 7-11μ.

Pond near Longwood. Pl. 8, Fig. 133.

60. O. CIRCINATUM Tiffany

Dioecious, nannandrous, idioandrosporous (?); oogonia 1 or 2, usually terminal, depressed-globose, with 4-9 rounded projections arranged in a median whorl, operculate, division inframedian; oospore depressed-globose to nearly globose, not quite filling oogonium, its wall smooth; suffultory cell sometimes enlarged (up to 8μ); upper part of filament nearly always circinate or irregularly contorted; vegetative cell capitellate; terminal cell, usually an oogonium, apically conic; basal cell subhemispheric; dwarf male unicellular, obovoid, small, situated on suffultory cell; vegetative cell 3-6 x 8-32μ; oogonium 16-20 x 12-16μ; oospore 14-18 x 10-13μ; dwarf male 3-4 x 6-7μ; basal cell 15-16 x 5-6μ.

Canal south of Arcadia. Pl. 6, Fig. 111.

61. O. PLATYGYNUM Wittrock

Dioecious, nannandrous, gynandrosporous and idioandrosporous; oogonia 1 or 2, depressed-obovoid, with 7-12 (more often 8) rounded projections arranged in a whorl around the middle, operculate, division inframedian; oospore depressed- or subdepressed-globose, not quite filling oogonium, spore-wall smooth; suffultory cell sometimes enlarged; androsporangia 1-3; vegetative

cell evidently capitellate; terminal cell apically obtuse; dwarf male unicellular, obovoid, small, on oogonium; vegetative cell 5-11 x 14-50μ; oogonium 20-30 x 16-24μ; oospore 16-24 x 13-20μ; androsporangium 6-8 x 7-8μ; dwarf male 4-6 x 8-12μ.

Swamps west of Immokalee and near Buckingham. Pl. 6, Fig. 109.

62. O. CONTORTUM Hallas

Dioecious, nannandrous, gynandrosporous; oogonium 1 (rarely 2), depressed-globose (rarely pyriform), operculate, division inframedian; oospore depressed (rarely globose), quite filling oogonium, spore-wall smooth; androsporangia 1-5, curved, hypogynous or rarely epigynous or scattered; dwarf male obovoid, unicellular, on oogonium; vegetative cell 5-7 x 20-60μ; oogonium 23-35 x 16-35μ; oospore 16-28 x 12-21μ; androsporangium 5-7 x 7-14μ; dwarf male 4 x 13μ.

Canal south of Arcadia. Pl. 6, Fig. 110.

63. O. LONGICOLLE Nordstedt

Dioecious, nannandrous; oogonia 1-7, pyriform, often vertically elongate, operculate, division median and narrow; oospore subdepressed-globose or subglobose, inflating oogonium medianly, not filling it longitudinally, spore-wall smooth; basal cell subhemispheric; dwarf male unicellular, obovoid, minute, on oogonium; vegetative cell 4-6 x 16-45μ; oogonium 13-16 x 16-32μ; oospore 12-15 x 10-16μ; dwarf male 2 x 4μ; basal cell 14 x 6μ.

Cypress swamp south of Arcadia. Pl. 7, Fig. 130.

64. O. SENEGALENSE (Nordst.) Tiffany

Dioecious, nannandrous; oogonia 1-5, pyriform, often elongate lengthwise, operculate, division median (rarely supramedian) and narrow; oospore subglobose to depressed-globose, sometimes inflating oogonium medianly but not filling it longitudinally, its wall smooth; basal cell subhemispheric; dwarf male unicellular, obovoid, minute, on oogonium, often lacking; vegetative cell 5-8 x 12-40μ; oogonium 16-21 x 14-32μ; oospore 14-20 x 11-19μ; dwarf male 1-2 x 2-3μ; basal cell 13-14 x 5-7μ.

Pool east of Alva; cypress swamps south of Arcadia and near Buckingham. Pl. 6, Fig. 100.

65. O. ROTHII Pringsheim

Dioecious, nannandrous, gynandrosporous; oogonia 1-3, subdepressed-globose, operculate, division median, narrow; oospore depressed-globose, almost filling oogonium, spore-wall smooth; androsporangia 1-4, subhypogynous, hypogynous, subepigynous, or scattered; vegetative cell 6-10 x 20-76μ; oogonium 20-27 x 16-27μ; oospore 17-25 x 14-20μ; androsporangium 6-8 x 5-10μ; dwarf male 4 x 11-12μ.

Pool east of Alva. Pl. 6, Fig. 97.

66. O. DECIPIENS Wittrock

Dioecious, nannandrous, gynandrosporous; oogonia 1-3, subdepressed-globose, operculate, division median, rather narrow; oospore subdepressed- or depressed-globose, almost filling the oogonium, spore-wall smooth; androsporangia 1-6, subepigynous, hypogynous, or scattered; dwarf male unicellular, usually on the oogonium; vegetative cell 9-12 x 28-80μ; oogonium 30-38 x 27-40μ; oospore 25-34 x 23-38μ; androsporangium 9-10 x 8-15μ; dwarf male 6-7 x 13-15μ.

Canal south of Arcadia. Pl. 6, Fig. 104.

66a. Var. AFRICANUM Tiffany

Smaller and idioandrosporous; vegetative cell 8-13 x 25-60μ; oogonium 25-32 x 24-32μ; oospore 24-30 x 23-28μ; androsporangium 7-11 x 9-13μ; dwarf male 6-7 x 9-12μ.

Cypress swamp south of Arcadia. Pl. 6, Fig. 105.

66b. Var. BERNARDENSE (Bates) Hirn

Smaller; gynandrosporous; androsporangia to 8-seriate; vegetative cell 8-12 x 18-45μ; oogonium 25-31 x 21-32μ; oospore 21-29 x 17-24μ; androsporangium 7-11 x 5-11μ; dwarf male 6-7 x 10-12μ.

Canal south of Arcadia.

67. O. ARESCHOUGII Wittrock

Dioecious, nannandrous, gynandrosporous; oogonia 1-6, subdepressed or depressed-pyriform-globose, operculate, division median and wide; oospore globose, rarely subdepressed-globose, not completely filling the oogonium lengthwise, spore-wall smooth; androsporangia 1-6, subepigynous or hypogynous or rarely scattered; vegetative cell capitellate; basal cell elongate; terminal cell, usually the oogonium, apically obtuse; dwarf male obovoid, unicellular, on oogonium; vegetative cell 8-13 x 35-75μ; oogonium 34-39 x 36-40μ; oospore 22-26 x 22-25μ; androsporangium 9-11 x 10-12μ; antheridium 6-7 x 13-15μ.

Near Taft. Pl. 6, Fig. 117.

68. O. SUBPLENUM Tiffany

Dioecious, nannandrous, idioandrosporous and gynandrosporous; oogonia 1-3, depressed-globose to depressed-pyriform-globose, division median and wide; oospore globose, not filling oogonium, its wall smooth; androsporangia to 11-seriate; dwarf male obovoid, 1-celled, on oogonium; vegetative cell, capitellate, 7-12 x 23-80μ; oogonium 29-38 x 26-41μ; oospore 21-28 x 19-26μ; androsporangium 7-10 x 7-11μ; dwarf male 6-7 x 6-10μ.

Near Taft. Pl. 6, Figs. 106, 107.

69. O. CONFERTUM Hirn

Dioecious, nannandrous, idioandrosporous (?); oogonia 1-4, depressed-globose or depressed-pyriform, operculate, division median, wide; oospore globose

or subdepressed-globose, not filling oogonium lengthwise, spore-wall smooth; vegetative cell capitellate; dwarf male obovoid, on oogonium; vegetative cell 19-26 x 66-105μ; oogonium 56-63 x 44-56μ; oospore 42-48 x 40-44μ; dwarf male 10-12 x 13-16μ.

Cypress swamp south of Arcadia. Pl. 6, Fig. 114.

70. O. BRASILIENSE Borge

Dioecious, nannandrous, idioandrosporous; oogonia 1-3, subdepressed-globose or subpyriform-globose, operculate, division median, wide; oospore subdepressed-globose, not quite filling oogonium, spore-wall smooth; androsporangia to 5-seriate; vegetative cell capitellate; dwarf male obovoid, unicellular, on oogonium; vegetative cell 16-22 x 35-95μ; oogonium 53-63 x 52-59μ; oospore 48-53 x 45-50μ; androsporangium 15-16 x 11-14μ; dwarf male 10-12 x 14-19μ.

Cypress swamp south of Arcadia. Pl. 6, Fig. 116.

71. O. OELANDICUM Wittrock

Dioecious, nannandrous, gynandrosporous; oogonia 1-7, depressed-globose, with 12-16 longitudinal ridges, operculate, division supramedian, rather broad; oospore depressed-globose, nearly filling oogonium, spore-wall smooth; androsporangia to 6-seriate; vegetative cell capitellate; terminal cell apically obtuse; dwarf male obovoid, unicellular, on oogonium; vegetative cell 10-15 x 25-125μ; oogonium 31-40 x 25-32μ; oospore 25-36 x 23-30μ; androsporangium 7-12 x 10-18μ; dwarf male 7-8 x 12-15μ.

Cypress swamp south of Arcadia. Pl. 6, Fig. 112.

72. O. COSTATUM Transeau

Dioecious, nannandrous, gynandrosporous; oogonium 1, depressed-globose, with verticillate folds forming distinct pointed projections at the suture, operculate, division narrow, supramedian; oospore depressed-globose, filling oogonium, spore-wall smooth; androsporangium hypogynous; vegetative cell usually capitellate; terminal cell with rounded apex; vegetative cell 12-15 x 50-70μ; oogonium 50- 55 x 40-44μ; oospore 48-53 x 36-42μ; androsporangium 12-13 x 10-12μ.

Cypress swamp south of Arcadia. Pl. 6, Fig. 118.

73. O. RUGULOSUM Nordstedt

Dioecious, nannandrous, gynandrosporous; oogonia 1 or 2, obovoid or obovoid-ellipsoid, operculate, division superior; oospore ellipsoid, nearly filling oogonium (or rarely globose-ellipsoid, not filling oogonium), spore-wall smooth; dwarf male on or near oogonium; androsporangium usually 1, hypogynous; antheridium exterior, 1-?, curved; terminal cell apically obtuse; vegetative cell 4-8 x 10-35μ; oogonium 16-20 x 22-29μ; oospore 15-18 x 19-25μ; androsporangium 6-8 x 10-11μ; antheridium 4-5 x 5-6μ; dwarf male 5-7 x 11-14μ.

Pool west of Okeechobee. Pl. 6, Fig. 98.

73a. Var. ROTUNDATUM (Hirn) Tiffany

Oogonium 1 or 2; oospore globose-ellipsoid or ellipsoid; vegetative cell 5-8 x 15-31μ; basal cell 7-8 x 22-27μ; oogonium 19-23 x 20-28μ; oospore 18-22 x 18-65μ; dwarf male 5-8 x 11-15μ; antheridium 4-6 x 4-6μ.

Pool west of Okeechobee. Pl. 6, Fig. 99; Pl. 8, Fig. 139.

74. O. RIGIDUM Hirn

Dioecious, nannandrous, gynandrosporous; oogonium 1, obovoid-globose, operculate, division superior; oospore globose, nearly filling oogonium, spore-wall smooth, often thick; androsporangia 1 or 2, epigynous, subepigynous or hypogynous; vegetative cell broadly capitellate; terminal cell obtuse; dwarf male curved, on oogonium; antheridium exterior, 1-?; vegetative cell 12-16 x 38-58μ; oogonium 35-43 x 35-48μ; oospore 32-38 x 32-38μ; androsporangium 10-11 x 11-12μ; dwarf male stipe 7-9 x 18-22μ; antheridium 5-7 x 6-7μ.

Roadside east of Naples; swamp south of La Belle. Pl. 6, Fig. 113.

75. O. MACRANDRIUM Wittrock

Dioecious, nannandrous; oogonia 1-4, globose-ovoid, operculate, division superior; oospore globose, rarely ovoid-globose, not completely filling the oogonium, spore-wall smooth; terminal cell obtuse or very shortly apiculate; dwarf male on or near the oogonium, stipe much curved, sometimes 2-3 celled; antheridia 1-7; vegetative cell 15-20 x 45-100μ; oogonium 36-42 x 43-54μ; oospore 31-37 x 33-39μ; dwarf male stipe 12-13 x 24-33μ; antheridium 9-10 x 7-10μ.

Ditch south of Ft. Myers . Pl. 6, Fig. 101.

75a. F. LUNDENSE (Wittr.) Hirn

Oogonium subobovoid-globose; oospore-wall sometimes thick; vegetative cell 13-21 x 13-50μ; oogonium 31-40 (45) x 34-43μ; oospore 29-36 (40) x 29-36 (40)μ; dwarf male stipe 10-15 x (21) 24-32μ; antheridium 8-10 x 6-9μ.

Roadside east of Naples and south of Okeechobee; pool near Ft. Myers. Pl. 6, Fig. 103.

75b. Var. HOHENHACKERII (Wittr.) Tiffany

Vegetative cell 12-15 x 24-45μ; oogonium, single, 29-33 x 30-35μ; oospore 27-31 x 28-31μ; androsporangium 11-13 x 10-14μ; dwarf male stipe 9-14 x 18-24μ; antheridium 5-6 x 5-8μ.

Ditch near Ft. Myers. Pl. 6, Fig. 102.

76. O. ACROSPORUM DeBary

Dioecious, nannandrous, gynandrosporous (or idioandrosporous); oogonium 1, terminal, ellipsoid, operculate, division supreme, operculum small and

deciduous; wall of oogonium with longitudinal, sometimes anastomosing, ridges on the inner suface; oospore quite filling the oogonium, outer layer of spore-wall with 23-30 longitudinal ridges, closely fitting in between the ridges of the oogonium, the inner smooth; basal cell elongate; terminal cell obtuse; androsporangia 1-8, hypogynous or scattered; dwarf male curved, on the suffultory cell, stipe sometimes 2-3 celled, upper cells long, antheridia exterior, 1 or 2; vegetative cell 12-21 x 40-125μ; suffultory cell 16-25 x 26-76μ; oogonium 35-48 x 50-63μ; androsporangium 16-21 x 12-15μ; upper cell of dwarf male stipe 6-8 x 55-71μ, the lower cell 9-12 x 30-38μ; antheridium 6-8 x 9-15μ.

Cypress swamp south of Arcadia; ponds west of Okeechobee and west of Daytona Beach. Pl. 7, Fig. 125.

77. O. TENTORIALE Nordstedt & Hirn

Dioecious, nannandrous; oogonium 1, terminal, broadly ellipsoid or obovoid-globose, division supreme, lid small, deciduous, oogonium wall longitudinally ribbed on the inner surface, ribs often anastomosate; oospore quite filling oogonium, outer layer of the spore-wall with 40-45 longitudinal, very finely crenulate ribs, closely filling in between the ribs of the oogonium, connected by delicate transverse lines, the inner layer smooth; basal cell elongate; terminal cell obtuse; dwarf male suberect, on suffultory cell, antheridium exterior 1-?; vegetative cell 20-33 (-37) x 60-225μ; oogonium 66-82 x 73-88μ; oospore 64-80 x 70-83μ; dwarf male stipe 10-15 x 37-48μ; antheridium 9-12 x 7μ.

Pond near Longwood. Pl. 7, Fig. 124.

78. O. WABASHENSE Tiffany

Dioecious, nannandrous, gynandrosporous; oogonia 2 or 3, ellipsoid or ovoid, often terminal, operculate, division supreme, lid often deciduous; oospore ellipsoid or ovoid (rarely globose), filling oogonium or not, spore-wall smooth; androsporangia 1-3, subepigynous; vegetative cell capitellate; basal cell elongate; dwarf male on oogonium; antheridium 1-?; vegetative cell 12-20 x 36-64μ; oogonium 36-42 x 44-60μ; oospore 34-38 x 40-55μ; androsporangium 12-16 x 10-20μ; dwarf male stipe 12-16 x 24-40μ; antheridium 7-12 x 6-10μ; basal cell 18-20 x 40-64μ.

Pond, junction of Highways 2 and 25. Pl. 6, Fig. 116.

79. O. OBTRUNCATUM Wittrock

Dioecious, nannandrous, gynandrosporous; oogonia 1-6, ellipsoid, or globose-ellipsoid, operculate, division supreme, operculum small and deciduous; oospore of same form as oogonium, nearly filling it, spore-wall smooth; vegetative cell evidently capitellate; basal cell elongate; terminal cell (often the oogonium) apically obtuse; dwarf male oblong-pyriform, curved, unicellular, on oogonium; vegetative cell 18-22 x 56-110μ; oogonium 45-55 x 56-68μ;

oospore 43-53 x 52-66μ; androsporangium 20 x 24μ; dwarf male stipe 17-20 x 36-40μ; antheridium 6-8 x 4-6μ.

Roadside south of La Belle. Pl. 7, Fig. 129.

79a. Var. ELLIPSOIDEUM Wittrock

Oogonia 1 or 2, ellipsoid, terminal; vegetative cell 17-23 x 54-110μ; oogonium 42-54 x 66-75μ; oospore 40-52 x 60-72μ.

Swamp north of Frontier. Pl. 8, Fig. 134.

80. O. COMPLETUM (Hirn) Tiffany

Dioecious, nannandrous, gynandrosporous; oogonia 1-3, broadly ellipsoid, operculate, division supreme, operculum small and deciduous; oospore broadly ellipsoid, nearly filling oogonium; spore-wall smooth; androsporangia 1-5, hypogynous or epigynous or subepigynous; terminal cell sometimes setiform; vegetative cell, capitellate, 18-22 x 66-150μ; oogonium 55-60 x 63-75μ; oospore 53-58 x 61-73μ; androsporangium 20-22 x 19-22μ.

Cypress swamp south of Arcadia. Pl. 7, Fig. 128.

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North American Species of Androsace

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The primulaceous genus *Androsace* comprises 85 to 90 species of annual and perennial herbs, occurring for the most part in the mountain and boreal-arctic regions of Eurasia and North America. The greatest concentration of species is found in the Sino-Himalayan area, while in North America the greatest concentration is in the Westren Cordillera.

The North American representation of the genus—six species and six subspecies—although small, offers problems of speciation and relationship which have not been well understood. The treatment of the genus given by Knuth (1905) is carefully done but is based on a meagre number of North American collections and the morphological distinctions used are often so arbitrary and unreliable that they apply equally well to a number of species. This is particularly true of corollar morphology for which the genus in North America offers only a stereotyped plan. The only treatment primarily concerned with North America is the revision presented by Harold St. John (1922) which covers certain of the species belonging to the annual section of the genus. With more abundant North American material St. John was able to correct many of the errors of Knuth and to bring together additional and significant characters for the separation of the entities. Most of the entities remain today as he delimited them but the failure to recognize the range of variation from field studies of certain of the Western Cordilleran forms has brought the perpetuation of some errors.

In our area, two species, *A. carinata* and *A. lehmanniana*, are caespitose perennials; the others are annuals or weakly-developed perennials. The annuals, particularly the units of *A. septentrionalis*, are apparently in continuing subspeciation at the present time. These subspecies, occurring for the most part in the central and southern Rocky Mountain region, appear to represent divergent populations of a more northern, perhaps preglacial, ancestor. Furthermore, they have progressed to a point in their evolution so as to be recognized as morphologically discrete units but not to a point as to prevent occasional genetic intermingling and the occurrence of intermediate forms among them.

The approach to the present study has been largely a morphological one, based on the examination of over 1700 herbarium specimens, including types and other critical material, from North America as well as from Europe and Asia. This has been supplemented with observations and collections in the field of six of the seven species and subspecies known to occur within the state of Colorado. However, additional field observations will help to make the study even more complete. Many of the annuals, because of their small and delicate parts, are easily overlooked in the field, although plentiful in their habitats. Too many collections have been made of single plants which often represent a seasonal or local variant and give only the slightest indication of

their normal range of variation in nature. A series of collections from a given station showing something of this variation or a series of collections made within a limited area in different habitats and at different altitudes would do much toward clearing up the puzzling intermediate forms often encountered in herbarium collections. In connection with this, local patterns of distribution must be more completely worked out so that their floristic significance and limits of variation as related to ecologic factors may also be better understood.

Taxonomic History of the Genus with Particular Reference to North America

The name *Androsace* was first used in 1700 by Tournefort (Instit. rei. herb., p. 123, pl. 46). In 1753 Linnaeus (Sp. Pl. 1:141-142) adopted the name to include six species, all of them European. Under the generic name *Aretia* he published a single species. This latter genus has since been relegated to the status of a section of *Androsace*. The type species of the genus is *A. carnea* L. although Britton and Brown (Illustr. Fl. No. U.S. and Canada, ed. 2. 2:709. 1913) indicate the Eurasiatic plant *A. maxima* L. A comparison, however, of the original descriptions of the genus[1] as given by both Linnaeus (Gen. Pl. ed. 5. 69. 1754) and Tournefort (*op. cit.*), shows that *A. maxima* probably represents an arbitrarily chosen type since it is the first species listed in "Species Plantarum." Linnaeus bases his description on the plate (pl. 46, *non vide*) in Tournefort's work. Furthermore in "Species Plantarum" under the species *A. lactea* and *A. carnea* he cites the reference to Tournefort's description of the genus. It would appear, then, that Linnaeus had one of these species in mind when he wrote his description. It may be said that the characters used by Linnaeus and Tournefort in their descriptions are so generalized that they might be equally descriptive of several species. From what can be inferred from the two descriptions, however, they seem to be in general agreement. All characters, save an important one, in Linnaeus' generic description agree equally well with both *A. lactea* and *A. carnea*. But his statement that the corolla lobes are obtuse and entire eliminates from consideration *A. lactea* which has distinctly notched corolla lobes. Consequently, *A. carnea*, which has the obtuse and entire corolla lobes, becomes the type species of the genus, actually the last one listed in "Species Plantarum."

The first species of *Androsace* to be described from North America proper was that of the relatively widespread Mississippi and Missouri valley plant, *A. occidentalis*. It was described by Pursh in 1814 (Fl. Am. Sept. 1:137) from a collection made by Nuttall "on the banks of the Missouri." Torrey in 1823 (Ann. Lyc. Nat. Hist. N. Y. 1:30-31. pl. 3. fig. 1.) described the perennial caespitose plant, *A. carinata* from a collection made by Edwin James on the alpine slopes of James Peak,[2] Colorado.

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1 Communicated through the kindness of Edith M. Vincent, Field Mus. Nat. Hist., Chicago.

2 Now known as Pikes Peak; see Ewan in *Trail and Timberline* No. 282 (June) 1942 on James' Colorado Explorations.

The first attempt at a synopsis of the North American species of the genus was that by Asa Gray (1878). Gray described four species and one variety, the latter being described as new. Three of the species he considered to be identical with European and Asiatic species. Between the years of 1894 and 1903 nine new species were described from Western North America. A number of these were based on young, immature or atypical plants, so that only one, or possibly two, are recognized today as valid.

In 1905, F. Pax and R. Knuth (*op. cit.*) monographed the *Primulaceae*. Their work recognizes 13 species and 7 varieties of *Androsace* native to North America, including the arctic regions around Bering Strait.

In 1922 St. John (*op. cit.*) published his revision treating only three annual species and their eight varieties, most of them as varieties of *A. septentrionalis* and *A. occidentalis*.

The most recent work on the genus is that of H. Handel-Mazzetti who published a revision of the Chinese species (1927). In addition to the recognition of 47 Chinese species, he created and redefined sections for the genus as a whole which are much improved over those previously established by Knuth. He discusses the relationships of these sections and adds a number of valuable notes more or less directly concerned with North American species.

Species Criteria and Morphology

Many of the North American forms of *Androsace,* form to form, show the same or a similar interplay of characters among the various units. Particularly is this true among the annuals, which apparently represent a relatively recent development in the genus. It is difficult to delimit species or to indicate relationships in the annuals because there is considerable intergradation. The annuals are also subject to a great deal of environmental or seasonal modification. Although the units are in some cases exceedingly variable, and might easily be subdivided into a number of biotypes or strains, the categories species and subspecies, as used in this paper, are intended to represent peaks of variation and appear to form the only convenient basis for giving the clearest idea of the pattern as it exists in nature. Consequently, in selecting characters to delimit the various units, it was necessary to choose several characters to indicate thereby in the aggregate something of their relationships. The accompanying key to the species and subspecies has been constructed with this factor of parallel development in mind and as a result has been made rather full to include a number of diagnostic characters.

The morphological characters of the genus with suggestions of their taxonomic value are as follows:

HABIT.—Our species of *Androsace* are of two growth habits: The species *A. carinata* and *A. lehmanniana* are perennials with a shortly-branched caudex, which forms loose clusters or mats of interrupted glomerules in *A. carinata* and is more densely caespitose in *A. lehmanniana*. The species *A. occidentalis* and *A. septentrionalis* and their variants are all annuals or winter annuals with a fibrous root system. Some of the subspecies, however, exhibit

a tendency towards a perennial habit. This occurs in *A. septentrionalis subumbellata* where a weakly-developed caudex can sometimes be observed. In *A. filiformis* there is also a weakly-developed caudex, the plant probably representing a short-lived perennial.

STEM.—The stems are scapiform. In the perennial forms they are simple and solitary from the basal cluster of leaves. In the annuals they are also simple but vary in number from one to many. *A. septentrionalis glandulosa*, for example, is characterized by having a single, central, well developed scape, with a few, weakly-developed lateral ones; other subspecies possess many well-developed scapes.

LEAVES.—The leaves are all basal, forming close rosulate clusters in the perennials or spreading in the annuals. In the perennials the leaves approach a condition of dimorphism, a feature useful in distinguishing the North American forms from the European (see discussion in the taxonomic treatment under *A. lehmanniana*). The leaves in the perennials and in most of the annuals are scarcely or only indistinctly petiolate. In the different subspecies of *A. septentrionalis* the leaves vary from linear to linear-lanceolate or oblanceolate, entire or denticulate in the distal portions, and are mostly obtuse to subacute. In *A. occidentalis* the leaves tend to be more ovate-lanceolate in shape and are slightly narrowed towards the base. In *A. filiformis* the leaves are ovate, obtuse, and contracted at the base into a long, narrow, somewhat winged, petiole.

HERBAGE.—The density and extent of pubescence is of some taxonomic importance in distinguishing the subspecies, particularly of the *A. septentrionalis* group. Although subject to considerable environmental modification certain general tendencies are shown among some of the subspecies. In *A. septentrionalis puberulenta*, for example, the plants typically have a puberulence of simple and branched hairs covering all parts of the plant, including the calyx lobes. In other subspecies the puberulence is restricted to the lower portions of the scapes and the leaves, the rest of the plant being more or less glabrous. The presence of short-stipitate, usually dark, glandular hairs in some subspecies furnishes a useful diagnostic character.

INFLORESCENCE.—The flowers are umbellate in all our species of *Androsace*. In the caespitose perennials the pedicels are often quite short but of equal length resulting in a subcapitate umbel. In the subspecies of *A. septentrionalis* the umbels may be rather compact and few-flowered, or they may be very diffuse with unequal rays and few to many-flowered, these features affording useful taxonomic characters.

BRACTS.—The bracts of the involucre are useful in distinguishing some of the species but are of little value in separating the subspecies. In the perennials they are linear-lanceolate to triangular-lanceolate. At their point of attachment to the scape they are slightly saccate. The bracts are usually incurved at the tip and tend to enclose the flower cluster. In *A. occidentalis* the bracts are ovate to ovate-lanceolate. In the *A. septentrionalis* group the bracts vary from slender subulate or acerose to narrowly lanceolate or triangular-lanceolate.

CALYX.—Considerable confusion seems to have arisen in determining species and particularly subspecies from the shape of the calyx. Distinctions such as "campanulate" and "obconical" are too generalized to state the condition in plants with accrescent calyces that are apt to vary considerably in shape from the flowering to the fruiting stage. In an attempt to apply more precise terms to the shapes of the calyx and to indicate that there are among them valuable taxonomic characters, a series of sketches (Figs. 1-5) has been made illustrating types of calyces for most of the annual forms. Each species or subspecies is represented by two or three sketches illustrating the shapes of the calyces at various stages of development. A description of each type is included with the descriptions of the subspecies. These types are used in distinguishing the various species and subspecies in the following systematic treatment but it must be realized that they represent the most frequent condition and are not necessarily illustrative of the variation that might occur within a single population.

COROLLA.—The corollas are so stereotyped in our species that they offer few characters of taxonomic value. In the perennials they are relatively large and rather showy, the lobes varying in length from 2-4 mm. or more, while in the annuals they are rather inconspicuous with lobes mostly less than 2 mm. long. Although the lobes in all our species are mostly rounded or obtuse I have observed in the field, in populations of *A. septentrionalis subulifera*, a tendency for the corolla lobes to be minutely apiculate. The tendency, however, was not constant and obtuse lobes were often found intermixed with the apiculate ones on the same plant. Whether or not additional taxonomic characters can be adduced from the shape of the corolla lobes remains for further study of the plants in the field, particularly since the corollas are so poorly preserved in most dried specimens.

Use of Subspecies

Subspecies are used in this paper to further the attempt at standardizing botanical nomenclature by restricting the varied usage of the term variety. Furthermore, in intergrading species complexes such as exemplified by the annual forms of *Androsace* the use of the subspecies concept to indicate the more or less distinct regional facies of species would appear to be more in harmony with recent genetical findings.

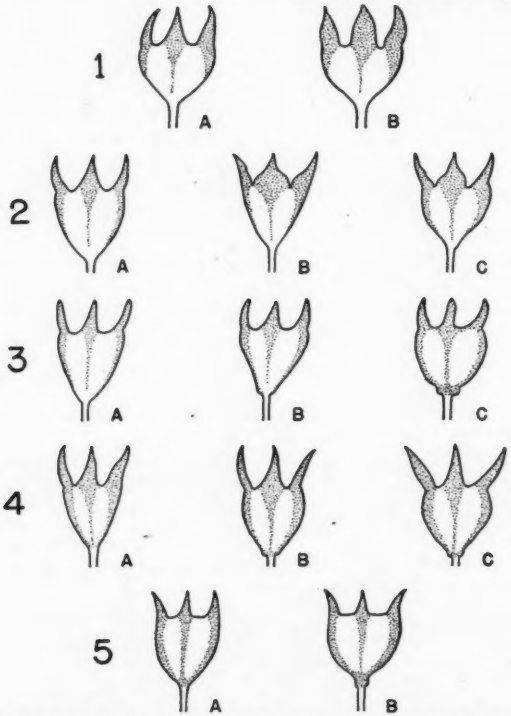
Previously named varieties are here cited as straight trinomials. However, these trinomials are not intended as new combinations. Their use obviates the cumbersome use of both the terms subspecies and variety and, moreover, avoids the confusion resulting from the practice of changing subspecies to varieties and *vice versa*. Tautonymous trinomials are used to indicate the nomenclatural type of a species. These are not to be considered as new combinations but are used merely for convenience in indicating the component parts of a species.

ACKNOWLEDGMENTS

The writer gratefully acknowledges the assistance given this study by Mr. Joseph Ewan, under whose direction and guidance the problem was undertaken. His criticisms and helpful interest in the problem have been of inestimable value. To many persons,

librarians and staff members, of several herbaria, I am particularly indebted for their help in checking bibliographical details. Finally, I am grateful to the curators of the following herbaria for their generosity in lending specimens and critical material:

Academy of Natural Sciences of Philadelphia
California Academy of Sciences
Canadian National Herbarium, Ottawa
Colorado College, Colorado Springs
Colorado State Agricultural College, Fort Collins
Gray Herbarium, Harvard University
Intermountain Herbarium, Utah State Agricultural College, Logan
New York Botanical Garden
Pomona College
Rocky Mountain Herbarium, University of Wyoming
United States National Arboretum
United States National Herbarium
University of Arizona
University of California
University of Colorado
University of Missouri
University of Notre Dame (Herbarium Greeneanum)
University of Oregon
and the private herbarium of Mr. A. O. Garrett of Salt Lake City, Utah.



Figs. 1-5. Calyces of North American subspecies of *Androsace* illustrating various stages of development. Fig. 1. *Androsace occidentalis occidentalis:* 1a, at anthesis, 1b, in fruit. Fig. 2. *Androsace septentrionalis subulifera:* 2a and 2b, at anthesis, 2c, in fruit. Fig. 3. *Androsace septentrionalis subumbellata:* 3a and 3b, at anthesis, 3c, in fruit. Fig. 4. *Androsace septentrionalis puberulenta:* 4a and 4b, at anthesis, 4c, in fruit. Fig. 5. *Androsace septentrionalis glandulosa:* 5a, at anthesis, 5b, in fruit.

Synopsis of the Genus Androsace in North America

A. Generic Description

ANDROSACE (Tourn.) L.

Androsace Tournefort, Inst. 123. pl. 46. 1700; Linnaeus, Gen. Pl. ed. 1. 40. 1737, Sp. Pl. 141-142. 1753, Gen. Pl. ed. 5. 69. 1754; Pursh, Fl. Am. Sept. **1**:137. 1814; Duby in DC. Prodr. **8**:47-55. 1844; Gray, A., Syn. Fl. N. Am. ed. 1, **2**: 60. 1878; Britton and Brown, Ill. Fl. No. U. S. ed. 1. **2**: 586. 1897; Knuth in Engler, Pflzr. IV. **237**:172-220. 1905; Rydberg, Fl. Colo. 261-263. 1906; Robinson and Fernald, Gray's New Man. Bot. ed. 7. 644. 1908; Coulter and Nelson, New Man. Rocky Mt. Bot. 374-375. 1909; Wooton and Standley, Contrib. U. S. Natl. Herb. **19**: (Fl. N. Mex.) 493-494. 1915; Henry, Fl. So. B.C. 237. 1915; Rydberg, Fl. Rocky Mts. ed. 1. 649-650. 1917; St. John in Victoria Memorial Mus. Memoir **126**:45-55. 1922; Jepson, Man. Fl. Pl. Calif. 755. 1925; Tidestrom, Contrib. U. S. Natl. Herb. **25**: (Fl. Utah and Nev.) 410-411. 1925; Rydberg, Fl. Prairies and Plains Cent. N. Am. 622. 1932; Munz, Man. So. Calif. Bot. 371. 1935; Hultén, Fl. Aleutian Islands 273-274. 1937; Jepson, Fl. Calif. **3**:72. 1939; Peck, Man. Higher Pls. Ore. 550. 1941.

Generic Synonymy:

Aretia L., Sp. Pl. 141. 1753.

Amadea Adans., Fam. **2**:230. 1763; Lunell, Am. Midland Nat. **4**:504. 1916.

Primula O. Ktze., Rev. gen. pl. **1**:400. 1891, in part; Derganc in Allgem. Bot. Zeit. **10**:110-111. 1904, in part.

Drosace A. Nels., New Man. Rocky Mt. Bot., 374. 1909; Wooton and Standley, Contrib. U. S. Natl. Herb. **19**: (Fl. New Mex.) 494-495. 1915; Rydberg, Fl. Rocky Mts. 648-649. 1917; Ashton, R.E., Pls. Rocky Mt. Natl. Park, 90. fig. 65. 1933.

Small annual, biennial or perennial herbs with basal leaves; scapes one to several, bearing terminal involucrate umbels; annuals with fibrous root system or the crown sometimes slightly thickened assuming a short-lived perennial habit (e.g. *A. filiformis* and *A. septentrionalis subumbellata*); perennials depressed, caespitose, with somewhat woody, branched caudex; leaves linear-lanceolate to oblanceolate or ovate-obovate, slightly or indistinctly petiolate; inflorescence subcapitate and few-flowered in perennials, sub-compact or diffuse and few to many-flowered in annuals; calyx hemispherical to subglobose or campanulate, 5-ridged or smooth, the 5 lobes narrowly subulate to deltoid and somewhat foliaceous, slightly or deeply lobed; corolla salverform or funnel-form, more or less coarctate at throat and 5-ridged within, often protruding as prominent rim at mouth of tube in perennials; corolla limb 5-lobed, small and inconspicuous in annuals with lobes often included, relatively conspicuous and surpassing the calyx in perennials; style solitary, short and included within corolla, bearing a small capitate stigma; anthers 5, oval or oblong, attached opposite corolla lobes by very short filaments, at or below the middle of the tube; ovary superior, 1-celled, with few to many ovules borne on a free central placenta; fruit a subglobose or globose capsule, shorter than, equal to or exceeding the calyx-tube, dehiscing longitudinally from apex to base by 5 coriaceous valves, few to many-seeded; seeds ovoid to elliptical or triquetrous, dark or pale brown, minutely pitted.

Type species: *Androsace carnea* L. (see Taxonomic History of the Genus, *ante*).

B. Key to the Species and Subspecies

1A. Caespitose perennials, the scapes solitary from close rosulate leaf clusters; umbel subcapitate, the pedicels short; corolla lobes mostly 2-4 mm. long, surpassing the calyx lobes.

2A. Plants 2-8 (or 10) cm. high; inner green leaves mostly obovate to oblanceolate or lingulate, obtuse; leaves ciliate with both surfaces more or less covered distally with white silky hairs; Alaska and northern Rocky Mountains .....1. *A. lehmanniana*

2B. Plants 1-4 (or 6) cm. high; inner green leaves mostly linear-lanceolate, acute or subacute; leaves ciliate, the surfaces sparingly white-silky pubescent or glabrous; southern Rocky Mountains .....2. *A. carinata*

1B. Annuals, or occasionally short-lived perennials; scapes one to many from spreading rosulate leaf clusters; pedicels various, ascending or divergent, forming compact (but never capitate) or diffuse, spreading umbels; corolla lobes mostly less than 2 mm.

3A. Calyx tube hemispherical to goblet-shaped in fruit; scapes and pedicels distinctly filiform; umbel hemispherical, the pedicels subequal; leaves ovate, with distinct, elongated petiole .....3. *A. filiformis*

3B. Calyx tube campanulate to subglobose-campanulate or obpyramidal in fruit; scapes and pedicels filiform or robust; umbels compact, the pedicels ascending, or umbels diffuse, the pedicels spreading; pedicels often quite variable in length; leaves scarcely or not at all contracted into a distinct petiole.

4A. Bracts of involucre lanceolate-ovate to ovate-obovate.

5A. Calyx lobes broadly lanceolate to deltoid and foliaceous; the lobes conspicuous by their greenness, contrasting with the whitish tube.

6A. Calyx lobes erect or somewhat spreading in fruit; scapes and pedicels erect to arched-ascending, or slightly flexuous; widespread species.

Scapes 1-10 (or 25) in number; umbel 2-10 flowered.....4. *A. occidentalis occidentalis*

Scapes mostly solitary; umbel 1-4-flowered .....4a. *A. occidentalis* forma *simplex*

6B. Calyx lobes widely spreading to arched-reflexed in fruit, conspicuously foliaceous, dark green; scapes and pedicels filiform; plants often sprawling; mts. of se. Arizona .....4b. *A. occidentalis arizonica*

5B. Calyx lobes subulate-acerose, pungently acute.....5. *A. elongata acuta*

4B. Bracts of involucre narrowly triangular to lanceolate, attenuate, or subulate to acerose, acute.

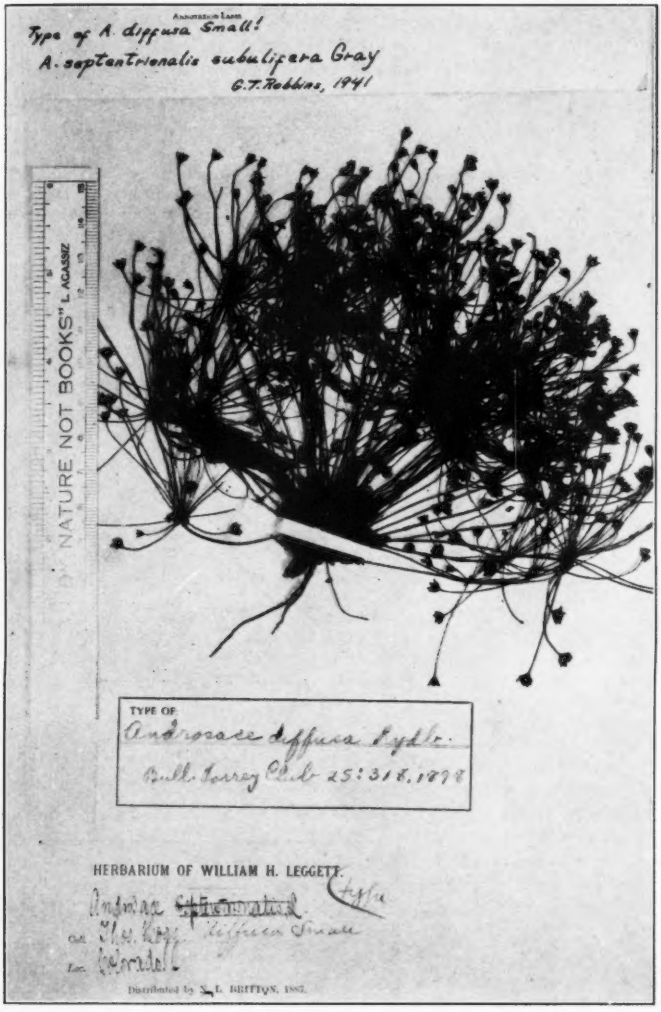
7A. Plants with mostly one central well-developed scape, lateral scapes poorly developed or absent; umbels more or less compact with ascending or arched-ascending pedicels.

8A. Scapes and pedicels densely puberulent to nearly glabrous; glandular hairs present; umbels compact, "*Allium*-like."

Scapes and pedicels more or less sparsely puberulent to nearly glabrous, with obscure, reddish-brown glandular hairs; boreal and arctic America .....6. *A. septentrionalis septentrionalis*

Scapes and pedicels puberulent with many reddish-brown glandular hairs, these most prominent at base of calyces, bracts and on the leaves; mts. of Colo., N. M. and Ariz. .....6a. *A septentrionalis glandulosa*

8B. Scapes and pedicels nearly glabrous, (with scattered puberulence in early development); glandular hairs absent; plant robust with rather thickish scapes and pedicels; umbel loosely com-


Type of A. diffusa Small!
A. septentrionalis subulifera Gray
C. T. Robbins, 1941
NATURE NOT BOOKS" L. AGASSIZ
TYPE OF
Androsace diffusa Rydb.
Bull. Torrey Club 25: 318. 1898
HERBARIUM OF WILLIAM H. LEGGETT

pact; capsule equalling or exceeding the broadly campanulate (almost hemispherical) calyx; e. Canada. ..... 6b. *A. septentrionalis robusta*

7B. Plants with usually several to many equally well-developed scapes; umbels more or less diffuse and spreading.

Calyx lobes slender-subulate to acerose, acute, 1/4-1/3 the length of the tube; plants 7-25 cm. high; pedicels 3-10 cm. long ..... 6c. *A. septentrionalis subulifera*

Calyx lobes narrowly triangular, acute to acuminate, 1/3-1/2 the length of the tube.

Plants glabrous except for minute puberulence on basal portion of scapes and leaves; dwarf tundra plants, 1-5 cm. high ..... 6d. *A. septentrionalis subumbellata*

Plants with herbage more or less puberulent on all parts, often including calyx lobes; puberulence on scapes dense, appearing scabridous, the dwarf tundra phase 2-5 cm. high, the lower altitude phase 6-10 (or 12-15) cm. high..... 6e. *A. septentrionalis puberulenta*

C. Treatment of the Species and Subspecies

1. ANDROSACE LEHMANNIANA Spreng., Isis (i.e. Encyclopädische Zeitung von Oken) **1**:1289. t.9. 1817, based on an undetermined collection from "Oriente."

A. chamaejasme sensu Amer. auctt., *non* Host.

A. chamaejasme var. *typica* (Derganc) Knuth, in Engler, Pflzr. IV. **237**:189. 1905, as to *Bourgeau* coll., Palliser's Brit. N. Am. Expl. Exped., 1857-8, from "Rocky Mts." (Alberta?), (Gray Herb.), not as to Eur. or Asiatic plants.

A. chamaejasme var. *arctica* Knuth, *op. cit.*, p. 190, as to *C. Wright* coll., U. S. North Pacific Expl. Exped., 1853-56 from Arakamtchetchene Island, Behring Straits (U. S. Natl. Herb.).

A. albertina Rydb., Bull. Torr. Club **40**:462. 1913, based on a coll. of *(Mr. and Mrs.) C. Van Brunt 77*, Aug. 1897, made at Lake Agnes, National Park, Banff, Alberta. Type (Herb. N. Y. Bot. Gard.) examined.

Drosace albertina Rydb., Fl. Rocky Mts. and Adj. Plains ed. 1. 649. 1917, based on last.

Plants loosely or cushion-caespitose, 2-8 (or 10) cm. high, from a slender taproot;[3] leaves varying from dimorphic to at times trimorphic; the outermost linear-lanceolate to lanceolate, acute, dry and membranous, light or dark brown at flowering; the inner whorl(s) obovate to lingulate, obtuse, green but somewhat membranous at flowering; innermost whorl (when present), linear-oblanceolate to subspatulate, $1/3$-$1/2$ again as long as the other leaves; leaves with or without a distinct midrib in the dry membranous condition; scapes, bracts, pedicels and calyces more or less arachnoid-pilose or silky, with long, jointed hairs; the hairs on the leaves thin, soft, directed forwards; bracts of involucre lanceolate to lanceolate-ovate, incurved near tip, and often extending to base or even tip of calyces; pedicels 2-4 (or 6) mm. long, forming a subcapitate 2-5-flowered umbel; calyx broadly campanulate, the tube scarious in the sinuses, the lobes ovate to ovate-lanceolate (or sometimes narrower), sub-

3 For a full discussion concerning the habit of this plant with a figure see Holm, T., Rep. Can. Arctic Exped. 1913-18. **5**(pt. B):51-52. 1922.

acute or obtuse, ½-¾ length of tube; corolla lobes ovate or obovate, entire and rounded, 2-4 mm. long, showy, mostly white or cream-colored, again pink and rose; corolla-tube coarctate, ridged, the ridges projecting as a rim around the mouth of the tube; capsule few-seeded.

Distribution: Asia. America: Along north coast of Alaska, east to vic. Coronation Gulf, south along west coast of Alaska to Alaska Peninsula, thence east to the Alaska Mts.; also in the northern Rocky Mts., principally Alberta (and Montana?).

Representative collections examined. NORTHWEST TERR.: Bernard Harbour, 1915, *Johansen 281*. ALASKA: Betw. Yukon River, Nation R. and Internatl. Bdry., 1930, *Mertie 107;* Teller Reindeer Sta., vic. Port Clarence, 1901, *Walpole 1409;* St. Lawrence Is., Iviktook Lagoon, 1931, *Mason;* Shumagin Islands, Sand Point, Popof Is., 1899, *Coville and Kearney 1795;* Naknek Lake, Dumpling Mt., Katmai Reg., 1918, *Hagelbarger 268;* vic. Karluk, Kodiak Is., 1903, *Rutter 186;* Igloo Creek, Mt. McKinley Natl. Park, 1932, *Dixon 26*. ALBERTA: Sulphur Mt., vic. Banff, 1916, *Moodie 1243;* Morley, foothills of Rocky Mts., 1885, *Macoun*.

Handel-Mazzetti (*l.c.*, p. 282) mentions having seen the type of this species in the Berlin herbarium, and makes comparisons with Asiatic and arctic American specimens, but gives no further information as to the collector or the nature of the type. Moreover, he comments upon the general agreement of the Chinese plants with the Berlin type and mentions the slight discrepancy between these and certain Caucasus plants. It seems that Handel-Mazzetti is possibly in error, however, mistaking the "Oriente" for the Far East rather than the Near East. Two lines of evidence appear to support this conclusion: (1) the citation of Caucasus specimens by Duby (Prodr. 8:51. 1844) under *A. chamaejasme*, where *A. lehmanniana* Spreng. is considered as a synonym, and (2) the citation of Asia Minor collections in the herbarium of Sprengel by Knuth (*l.c.*, p. 190) under *A. chamaejasme* var. *capitata* (Willd.) Knuth, where *A. lehmanniana* Spreng. is considered as a synonym.

A. lehmanniana Spreng., as Handel-Mazzetti construes it, is clearly distinguished from *A. chamaejasme* Host of Europe by a trimorphic condition of the leaves in the latter species. In view of this, and the fact that the name has been adopted by Hultèn and others, it seems advisable to retain the name until further studies can be made of the type and the related Caucasus plants that may represent transitional forms with true European *A. chamaejasme* Host.

It seems likely that these two species (*A. chamaejasme* Host and *A. lehmanniana* Spreng.) have had a common origin, probably from a northern Asiatic center as Holm[4] has suggested. The lines of evidence which seem to support this conclusion are: (1) the more or less widespread northern occurrence of the Asiatic and American forms, (2) the more advanced development of the species morphologically in the mountains to the south, (particularly *A. chamaejasme* Host of the Alps and *A. carinata* Torr. of the Rockies, and (3) the close morphological similarity among the various units.

4 See Holm, T., Vegetation of the Alpine Region of the Rocky Mountains in Colorado. Mem. Nat. Acad. Sci. **19**:30. 1923.

The characters which Rydberg used to distinguish the species *A. albertina* from the European *A. chamaejasme* Host were its narrower leaves and bracts and less pulvinate habit. Assuming that Rydberg also applied these distinctions to the new species to distinguish it from the Alaskan plants, I have made an extensive comparison of these characters in both Alaskan and Alberta specimens and have found few morphological differences. Although the tendency towards narrower leaves and bracts and a more loosely caespitose habit exists among the Alberta plants, this tendency also occurs in plants from Alaska and specific or subspecific lines readily break down. *A. albertina* is perhaps best considered as a local race of *A. lehmanniana*, this viewpoint supported furthermore by its apparently rather limited range. Montana collections cited in the literature have not been seen but are probably referable to this form.

2. ANDROSACE CARINATA Torr. in Ann. Lyc. Nat. Hist. N.Y. **1**:30-31. pl. 3, fig. 1. 1823, based on an *Edwin James* coll., Jame's [Pikes] Peak, July, 1820, in Torrey Herb., N.Y. Bot. Gard. Fragment of type (Gray Herb.) seen.

A. chamaejasme sensu Amer. auctt. *non* Host.

Primula carinata (Torr.) Derganc in Allgem. Bot. Zeit. **10**:110. 1904.

A. chamaejasme var. *typica* (Derganc) R. Knuth, in Engler, Pflzr. IV. **237**:189. 1905, as to *John Ball* coll., Iter Boreali-Amer. 1884, Pikes Peak, (Gray Herb.), not as to Eur. or Asiatic plants.

A. chamaejasme var. *carinata* (Torr.) Knuth, in Engler, *op. cit.*, p. 190. 1905.

Douglasia johnstoni A. Nels., Proc. Biol. Soc. Wash. **20**:37. 1907, based on *E. L. Johnston 339* from Long's Peak, Colo., 16 VIII 1906, in Rocky Mt. Herb. Placed in synonymy by A. Nels. under the following binomial:

Drosace carinata (Torr.) A. Nels. New Man. Rocky Mt. Bot. 374. 1909.

Drosace chamaejasme (Willd.) A. Nels. ex Ashton, Pls. Rocky Mt. Natl. Park 60, fig. 65. 1933, possibly an unintentional mistake.

Plants loosely or depressed-caespitose, only slightly cushioned, 1-5 (or 8) cm. tall, from a slender taproot; leaves dimorphic, the outermost broadly linear to lanceolate, scarcely narrowed at the base, acute, dry and membranous and light or dark brown at flowering; the inner whorl(s) lanceolate to oblanceolate, scarcely narrowed at the base, subacute, green and subcoriaceous at flowering, often thickened at the tip; midrib sometimes prominent near tips of green leaves, often obscure; herbage more or less densely arachnoid-pilose or silky (sometimes sparingly so), with long, jointed hairs; the leaves ciliate, surfaces sparingly hairy, the hairs mostly spreading or sometimes directed forwards; bracts of involucre linear-lanceolate to lanceolate, incurved near tip and nearly enclosing umbels; umbel subcapitate, 2-5-flowered, the pedicels 2-4 (or 5) mm. long; calyx broadly campanulate, the tube scarious in sinuses, the lobes lanceolate-ovate, subacute, ½-¾ length of tube; corolla lobes ovate or obovate, entire and rounded, 2-3 (or 4) mm. long, showy, mostly white or cream-colored, with a yellow, orange or pinkish eye (often on same plant); corolla tube coarctate, ridged, the ridges often projecting as a prominent rim around mouth of tube, capsule few-seeded.

Distribution: Mountains of Colorado and adjacent Utah at 11,000-14,000 ft. altitude.

Representative collection examined. COLORADO: El Paso Co.: Pikes Peak: Bottomless Pit, 1901, *Clements 416;* Windy Point, 1920, *I. M. Johnston 2589;* Custer Co.: Sangre de Cristo Mts., 1935, *Penland 1235;* Costilla Co.: Culebra Peak, 1930, *Penland;* Pitkin Co.: Capitol Peak, 1938, *Penland 1513;* Clear Creek Co.: "Rocky Mt. Alpine Flora, Lat. 39°-41°," *Hall and Harbour 202* 5; Mt. Evans, 1873, *E. L. Greene 42.* UTAH: Grand Co.: Mt. Waas (*not* Haas), La Sal Mt., 1899, *Purpus 6557;* La Sal Mts., 1924, *Payson 4034.*

This species superficially resembles *A. lehmanniana* in appearance but can be distinguished from it by its lower and more loosely caespitose habit and its somewhat thickish, coriaceous leaves which form close clusters at the base of the scapes. The leaves are also somewhat narrower and more acute. The keeled aspect of the leaves, pointed out by Torrey as a useful character of recognition, varies so greatly from specimen to specimen that there is little value in it. The carination appears most prominently in the older leaves, while the younger leaves may be slightly keeled near the tip or not at all. This same feature is also observed in *A. lehmanniana.* In an evolutionary sense this species is probably closely related to *A. lehmanniana* but on the basis of its geographical isolation and its divergence along somewhat distinct morphological lines it seems best to retain it as a distinct species.

The segregate genus *Drosace* was proposed by Aven Nelson (in Coulter and Nelson, New Man. Rocky Mt. Bot. 374. 1909) to include this single North American species. Dr. Nelson's separation of this species from *Androsace* was apparently made to distinguish the perennial caespitose plant from the other species which are mostly annuals. I believe, however, that the maintenance of a distinct genus for the perennials is untenable and only confuses the evolutionary pattern of the group. Handel-Mazzetti has pointed out (*l.c.*, p. 296) the strong connection, as exemplified by certain European species, of the annual with the perennial sections of the genus. The presence in these other floras of closely related as well as an intergrading series of species which appear to form a transition from the perennial to the annual forms offers a strong basis for considering the present forms as members of a single genus.

3. ANDROSACE FILIFORMIS Retz., Obs. Bot., fasc. 2, 10-11. 1781, based in part on *A. elongata sensu* Gmelin, Fl. Sibirica 4:81. t. 44. fig. 4. 1769, "minus bona," (*non vide*) and in part on a collection from Siberia taken by Pallas (cf. DC., Prodr. 8:53. 1844), *non* L. Type to be looked for in U.S.S.R. Acad. Sci. Herb.

A. capillaris Greene in Pittonia 4:148. 1900, based on N. Am. colls.

Further synonymy concerning species in Eurasia given by Pax and Knuth (*loc. cit.*, p. 217).

Slender, pale green annuals or short-lived perennials with a slightly thickened root crown; plants 5-10 (or 15) cm. high, glabrous except for a few,

5 Possibly from Pendeton Mt. above Silver Plume (*Ewan 14500* on 1 VIII 1942) —the only loc. in upper Clear Creek drainage *fide* Claire Norton.

minute, dark glandular hairs at base of calyces and bracts (seen under a strong lens); leaves ovate or ovate-lanceolate, 1-3 cm. long, petiolate, denticulate; scapes filiform, striate, mostly erect; bracts of involucre minute, subulate; pedicels filiform, subequal, forming an hemispherical umbel; calyx-tube hemispherical to goblet-shaped, the foliaceous lobes 3-nerved, scarious margined, triangular, becoming dry and papery with age; corollas white, minute, at length much exceeding calyx, the lobes obtuse, persistent and reflexed on the oval or subglobose capsule; capsule much exceeding calyx, the wall thin, transparent, capped by 5 coriaceous valves; seeds minute, numerous, light brown.

Distribution: Asia: From Karelian Coast of w. Russia, e. to Altai Mts. and Manchuria to Kamtchatka (*fide Hultèn*). America: Wet margins of streams and lakes from northern Colo. and Utah north to Wyo., Mont., and Idaho, w. to sw. Wash. and adjacent Oregon; mostly at elevations of 6,500-9,000 ft., but as low as 100 ft. in the lower Columbia River region.

Representative collections examined. COLORADO: Powell's Colo. Expl. Exped., 1868, *Vasey 375;* Clear Creek Co. (?): Rocky Mt. Flora, lat. 39°-41°, *Hall and Harbour 375;* Garfield Co.: Trappers Lake, 1938, *Ramaley and Ewan 16436;* Routt Co.: Steamboat Springs, 1891, *Crandall 505;* Grand Co.: Arrowhead, 1905, *Huestis;* Larimer Co.: Chambers Lake, 1934, *Zobel;* Gilpin Co.: Smartweed Lake, Rollinsville, 1911, *W. W. Robbins 8744;* Summit Co.: Breckenridge, 1901, *Mackenzie 123.* WYOMING: Albany Co.: Centennial Mt., 1902, *A. Nelson 8785;* Fremont Co.: Fremont's 1st Exp., (Sweetwater River, Aug. 5, 1842), *Fremont;* Teton Co.: Two-gwo-tee Pass, 1932, *L. Williams 934;* Yellowstone Natl. Park: Glen Creek, 1899, *A. and E. Nelson 5571;* Sheridan-Johnson Co.: Betw. Sheridan and Buffalo, 1900, *Tweedy 3487;* Co. undet.: French Cr., Big Horn Mts., 1898, *T. A. Williams.* MONTANA: Park Co.: Cottonwood Cr., nw. Wilsall, 1916, *Suksdorf 216;* Gallatin Co.: Spanish Basin, 1897, *Rydberg and Bessey 4676;* Ravalli Co.: Alta, 1909, *M. E. Jones;* Missoula Co.: Blackfoot Valley, 1923, *Kirkwood 1498;* Carbon Co.: Bridger, Bracket Cr. Divide, 1902, *Blankinship;* Powell Co. (?): Deer Lodge Valley, Echo Lake, 1906, *M. E. Jones.* IDAHO: Gooding Co.: "Central chain of the R. Mts.," *Nuttall,* (probably vic. Gooding, where Nuttall collected Aug. 11-13, 1834); Custer Co.: Morgan Cr., Challis Forest, 1917, *Eggleston 13970;* Fremont Co.: Henry Lake, 1920, *Payson 1994.* WASHINGTON: Klickitat Co.: Bingen, 1905, *Suksdorf 5044.* OREGON: Washington Co.: Forest Grove, 1887, *L. F. Henderson;* Gaston, 1927, *Peck 14805* (fide M. E. Peck).

I have had the opportunity of studying a number of collections of this species from localities in northwestern Russia and northern Asia and have found them to be practically indistinguishable from the North American form. The only divergent tendency noted in the Eurasiatic plants is that of a taller, slightly more robust plant. This seems, however, an insufficient basis for recognizing the Eurasiatic plant as a separate species. Greene distinguished *A. capillaris* from Eurasiatic *A. filiformis* on the basis of the perennial habit of the former. This distinction, however, breaks down with the occurrence in the Eurasiatic plants of the same tendency toward the development of a slightly thickened root crown as noted in the North American plants. A collection from Siberia, near Tjumen, (*Larionov,* 1921, N. Y. Bot. Gard.), illustrates well this tendency toward a short-lived perennial habit.

4. ANDROSACE OCCIDENTALIS Pursh, Fl. Am. Sept. 1:137. 1814, based on a *Nuttall* collection, "banks of the Missouri." We know that Nuttall men-

tions[6] collecting this species on his journey of 1811 up the Missouri River at Maha Village, within the present limits of Nebraska. It appears likely that the type specimen was taken at this locality. A specimen in Acad. Nat. Sci., Philadelphia, bearing the label "Louisiana Nuttall" with an annotation by Redfield that it is Pursh's specimen, apparently the actual type, has been studied.

A. platysepala Woot. and Standl., Bull. Torr. Club **34**:519-520. 1907, based on *Metcalfe 1547*, 30 III. 1905, from Kingston, Sierra Co., N. Mex. Type (U. S. Natl. Herb. 564330) examined. Paratype, Bear Mt. near Silver City, N. M., *Metcalfe 35* (in Rocky Mt. Herb.) examined.

Amadea occidentalis (Pursh) Lunell, Am. Midland Nat. **4**:504. 1916, based on foregoing.

Small, rather inconspicuous annuals, 3-8 (or 10) cm. high; scapes 1-10 (or 25) in number, often with an erect central scape and several arched-ascending lateral ones, sometimes flexuous; pedicels 2-10-flowered, unequal, erect or arched-ascending; leaves ovate-lanceolate to nearly linear, obtuse, entire or sparingly denticulate, slightly petiolate, glabrous beneath, upper surface and margin covered with short, stiff, usually simple white hairs; herbage, including calyx lobes, more or less puberulent; bracts of involucre lanceolate-ovate to ovate, acute, often reddish-tipped; calyx-tube subglobose-campanulate to obpyramidal in fruit, whitish or greenish-white, noticeably contrasting with the broadly lanceolate or deltoid lobes, these bright green, $1/3$-$1/2$ length of tube; the calyx tube broadly ridged, the lobes rounded, not ridged, more or less puberulent, reddish-tipped and mucronulate; corolla white, small, lobes obtuse, included within calyx; capsule rotund, included within calyx-tube; seeds many, small, blackish.

Distribution: Widespread throughout the Mississippi, Missouri and Arkansas river valleys, s. from so. Alta. and Man. to ne. Texas, e. to w. Ind. and w. to vic. 100th meridian, appearing again (mostly at elevations of 4000-5000 ft.) on the foothills of the Rocky Mts. of Colo., Utah, Mont. and n. to sw. B. C., also in the mts. of sw. N. Mex. and se. Ariz.

Representative collections examined. ALBERTA: Rosedale, 1915, *Moodie 831*. MANITOBA: Brandon, 1896, *Macoun* (ex Herb. Geol. Surv. Can. 12727). B. C.: Spence's Bridge, 1875, *Macoun 1205*. NORTH DAKOTA: Cass Co.: Fargo, 1906, *Bolley*, Morton Co.: Mandan, 1912, *Eggleston 7822;* McHenry Co.: Towner, 1908, *Lunell;* Ramsey Co.: Church's Ferry, 1912, *Bergman 1483*. MINNESOTA: Blue Earth Co.: Minneopa Falls, 1882, *Leiberg;* Chippewa Co.: Montevideo, 1895, *Moyer*. WISCONSIN: Sauk Co.: Baraboa, 1861, *Hale;* Dane Co.: Prairie du Sac, 1932, *Fassett 14231;* Polk Co.: St. Croix Falls, 1899, *C. F. Baker*. INDIANA: Tippecanoe Co.: Along Monon R. R. s. Big Wea Cr., 1934, *Deam 54758*. ILLINOIS: Peoria Co.: Peoria, 1904, *McDonald;* Kankakee Co.: Kankakee, 1861, *Hale;* Winnebago Co.: Rockford, *Norton;* St. Clair Co.: Falling Springs, 1930, *Goodman and Hitchcock 1066*. IOWA: Scott Co.: Davenprt, (1865?), *Parry;* Winneshiek Co.: Decorah, 1895, *Holway;* Polk Co.: Des Moines, 1938, *Hayden 11249*. SOUTH DAKOTA: Co. Undet.: Old Fort Lookout, *Sutton Hayes 557;* Minnehaha Co.: Sioux Falls, 1894, *Thornber;* Butte Co.: Newell, 1913, *Carr 12;* Spink Co.: Mellette, 1941, *Brenckle 4102;* Custer Co.: Wind Cave, Black Hills, 1927, *Hayward 1661*. NEBRASKA: Custer Co.: Callaway, 1901, *Bates;* Otoe Co.: Nebraska City, 1900, *Thornber;* Lancaster Co.: Lincoln, 1892,

6 See Pennell, F. W., in Bartonia **18**:13. 1936.

Turrell; Kearney Co.: Minden, 1932, *Hapeman.* KANSAS: Ellis Co.: Ellis, 1877, *S. Watson;* Cloud Co.: Aurora, 1936, *Fraser 182* (Pl. Exsicc. Gray. 675); Riley Co.: Manhattan, 1920, *Gates 11287;* Sedgwick Co.: Wichita, 1903, *Poole 29;* Miami Co.: *sine loco,* 1885, *Oyster 5221.* MISSOURI: St. Louis Co.: St. Louis, 1842, *Engelmann;* Sugar Cr., near Kirkwood, 1921, *Payson 1657;* Jackson Co.: Independence, 1894, *Bush 259;* Daviess Co.: Grand River, e. Gallatin, 1935, *Steyermark 18832;* Dade Co.: Turnback, 1929, *E. J. Palmer 35609;* Phelps Co.: Maramec Spring, 1933, *Drouet 323;* Moniteau Co.: Jamestown, 1932, *Drouet;* Boone Co.: Balanced Rock s. Columbia, 1935, *Drouet 1870.*

ARKANSAS: Washington Co.: Fayetteville, "May," *F. L. Harvey 53.* OKLAHOMA: Woods Co.: Cora, 1913, *C. W. Stevens 244;* Alfalfa Co.: Ingersoll, 1902, *Canby 93;* Comanche Co.: Fort Sill, 1916, *Mrs. J. Clemens 11722;* Murray Co.: Crusher Spur, 1913, *C. W. Stevens* 31; Oklahoma Co.: near Oklahoma City, 1913, *C. W. Stevens 154½;* Kingfisher Co.: Huntsville, 1896, *L. A. Blankinship;* Payne Co.: 14 m. se. Stillwater, 1934, *Dahms 64;* Pittsburg Co.: *sine loco,* 1935, *McClary.* TEXAS: Dallas Co.: Dallas, 1874, *J. Reverchon* (Curtiss N. Am. Pls., 1794); Tarrant Co.: *sine loco,* 1919, *Ruth 701;* Young Co.: Belknap, *Sutton Hayes;* Tom Green Co.: *sine loco,* 1936, *Cory.* NEW MEXICO: Grant Co.: Silver City, 1919, *Eastwood 8218,* in part. ARIZONA: Co. undet: (probably Pima Co.): "moist places of the southwestern plains and mountains" (probably Santa Catalina Mts., se. Ariz.), Mar. and Apr. 1884, *C. G. Pringle,* in part; Santa "Catarina" (Catalina) Mts., 1880, *Lemmon 288;* Coconino Co.: Grand Canyon, 1903, *M. E. Jones;* Pima Co.: Fort (or Camp) Lowell, *Lemmon;* Altar Valley, 1906, *Spalding;* Tanque Verde Mts., Tucson, 1935, *Nelson 1434;* Santa Cruz Co.: Tumacacori Mts., 1932, *Fosberg 7501;* "Massacre Camp" (Atasco Mts.), 1935, *Nelson 1479.* COLORADO: Boulder Co.: Boulder, 1916, *Ramaley 10601;* Boulder, 1941, *C. T. Robbins 364;* Jefferson Co.: "Golden City," 1870, *E. L. Greene 259;* Larimer Co.: Spring Canyon, 1919, *Osterhout 5885;* Arapahoe Co.: Wolhurst, 1920, *Clokey et al.;* La Plata Co.: Los Pinos (Bayfield), 1899, *C. F. Baker 514;* Montrose Co.: Naturita, 1914, *Payson 269;* Mesa Co.: Grand Junction, 1891, *M. E. Jones.* WYOMING: Crook Co.: 7 mi. nw. Hulett, 1935, *Ownbey 565;* Sheridan Co.: Little Goose Canyon, 1909, *Willits 27.* UTAH: Co. undet.: White River, 1908, *M. E. Jones.* MONTANA: Gallatin Co.: Bozeman, 1905, *Blankinship 339;* Missoula Co.: Camas Prairie, Blackfoot Valley, 1933, *C. L. Hitchcock* 1558.

St. John (*l.c.,* p. 53) selects a collection (U.S. Natl. Herb. 48677) as the type of this species. The label bears the name of the species in the handwriting of Asa Gray and the additional information "Cedar Creek, Camp 79, Apr. 24" in an unidentified handwriting. St. John attributes this collection to Nuttall from Cedar Creek, *Missouri,* April 24, *1810.* That this collection was ever made by Nuttall, seems quite unlikely. We know from the account of the travels of Nuttall as given by F. W. Pennell (*op. cit.*) that Nutall mentions in his "Genera" that *Androsace occidentalis* was collected at "Maha Village" where his party tarried from May 11-14, *1811* (although Nuttall credits the plant to April). This locality "was apparently in the present Omaha Reserve on the western (Nebraska) side of the Missouri some ten or twenty miles below Sioux City, Iowa." Furthermore, we learn from this account (*loc. cit.,* p. 8) that on April 22, *1810,* Nuttall was in Pittsburgh on his way to Detroit. The specimen in the herbarium of the Acad. Nat. Sci. at Philadelphia bearing the label "Louisiana Nuttall" written in Lambert's hand and having the annotation by Redfield that it was Pursh's specimen of this species appears to be the actual type.

Wooton and Standley distinguished *A. platysepala* from *A. occidentalis* on the basis of its broader, toothed leaves and its broader bracts. These char-

acters are well shown by both the type and paratype specimens and also by an additional collection from Silver City, N. M. (*Carlson* in 1915, Calif. Acad. Sci. Herb.). It is here recognized as merely a local phase of *A. occidentalis*. Further evidence for this view is to be found among collections, notably *Eastwood 8218* (Gray Herb. and Calif. Acad. Sci. Herb.) from the same area which more nearly approach the typical form of *A. occidentalis*.

4a. **Androsace occidentalis** forma **simplex** (Rydb.) comb. nov., based on *A. simplex* Rydb., Bull. Torr. Club **40**:462. 1913, in turn based on *Elrod et al. 33* from Missoula, Montana, V 1897, (N. Y. Bot. Gard.) examined. Paratypes: *M. E. Jones* from Salt Lake City, Utah, V 1882, (Univ. Calif. and Calif. Acad. Sci.) examined; *Macoun s. n.* from Lytton, B. C., 17 IV 1889.

A. occidentalis var. *simplex* (Rydb.) St. John, Victoria Memorial Mus. Memoir **126**:53. 1922.

Differing from *A. occidentalis occidentalis* only in having solitary scapes, a 1-4-flowered umbel, and usually smaller, more acute bracts and calyx lobes.

Distribution: Occasional throughout the range of the species in the Rocky Mountains and Great Basin region; appearing to become a dominant form in sw. Mont., ne. Utah and e. central Calif.

Representative collections examined. NEW MEXICO: Grant Co.: Silver City, 1919, *Eastwood 8218*, in part. COLORADO: Mesa Co.: Grand Junction, 1912, *Eastwood*. MONTANA: Missoula Co.: Camas Prairie, Blackfoot Valley, 1933, *C. L. Hitchcock 1558*; Gallatin Co. (?): Bridger Canyon, 1901, *W. W. Jones*. UTAH: Utah Co.: East Provo, 1935, *Harrison 6504*; Salt Lake Co.: Salt Lake City, June 1883, *M. E. Jones*. ARIZONA: Coconino Co.: Grand Canyon, *Eastwood*. CALIFORNIA: Placer Co.: Emigrant Gap, 1882, *M. E. Jones*. B. C.: Kamloops, 1935, *McCabe 1956*.

The sporadic occurrence of this form with populations of typical *A. occidentalis* (e.g. *G. T. Robbins 364* from Boulder, Colo., and *Payson 269* from Naturita, Colo.), together with its slight morphological differences, are the basis for considering *A. simplex* only a minor form of the species. The California collection cited above represents the only record of *A. occidentalis*, in any phase, from that state. Because of its delicate habit is is likely that it has often been overlooked in the field.

St. John includes under his var. *simplex* plants from the eastern part of the range of the species which have the narrowly deltoid or almost subulate calyx lobes but which otherwise possess the more vogorous branched habit of the species. *Forma simplex* is here retained only for those plants occurring in the mountainous regions of western North America. A general tendency toward smaller plants with a reduced number of scapes has been noted in populations of typical *A. occidentalis* occurring in this area and it may represent an ecologic adaptation to drier habitats.

4b. ANDROSACE OCCIDENTALIS ARIZONICA (Gray) St. John, Victoria Memorial Mus. Memoir **126**:54. 1922, *pro var. sed sensu emendo*, based on:

A. arizonica Gray, Proc. Amer. Acad. **17**:221-222. 1882, in turn based on *C. C. Pringle 330* from Santa Catalina Mts., Ariz., 19 IV 1881. Type (Gray Herb.) examined.

Primula arizonica (Gray) Derganc, Allgem. Bot. Zeit. **10**:110. 1904.

Annual plants 4-8 (or 10) cm. high, with 1-many filiform scapes, the scapes decumbent and spreading or flexuously ascending; pedicels filiform, lax and flexuous, unequal; leaves thin, linear-lanceolate to ovate, 7-12 (or 20) mm. long, entire, or sparingly denticulate; bracts of involucre ovate, acute, thin and membranous; calyx-tube broadly campanulate; the lobes ovate-lanceolate, large and foliaceous, spreading or arched-reflexed; corolla very small, included; capsule exposed by reflexed calyx-lobes, but usually included; seeds few (5-15), slightly larger than in the species.

Distribution: Apparently localized in the mountains of southern Arizona.

Representative collections examined. ARIZONA: Co. undet.: "Moist places of the southwestern plains and mountains," 1884, *Pringle*, in part; Pima Co.: Sierra Tucson, 1884, *W. F. Parish 216;* Santa Rita Mts., Stone Cabin Canyon, 1903, *Thornber* (707?); Toro Canyon, Baboquivari Mts., 1927, *Peebles et al. 3797;* San Pedro River, Redington, 1935, *Maguire 10022;* Pinal Co.: Oracle, 1905, *Thornber;* 46 mi. n. Tucson, 1935, *Maguire 10250;* Graham Co.: Bonita Canyon, Gila Range, 20 mi. n. Safford, 1935, *Maguire 10166;* 5 mi. e. Stockton Pass, Pinaleno Mts., 1935, *Maguire 10162A.*

The following collections appear to be intermediate between this subspecies and typical *A. occidentalis:* Pima Co.: Catlitt Ranch, near Arivaca, 1915, *Thornber 7691;* Santa Rita Mts., 1919, *Eastwood 8106;* Gila Co.: betw. Payson and Pine, 1929, *Eastwood 17193.*

This is a strikingly well-marked subspecies intergrading to some extent with *A. occidentalis occidentalis* and possessing a number of characters in common, but representing a distinct morphological type. Collections of this plant are exceedingly few in herbaria, representing chiefly only two or three early collections. Further collections from new stations should indicate to what extent this subspecies overlaps areally *A. occidentalis occidentalis.*

As St. John has pointed out (*l.c.*, p. 54), Pringle's collection of 1884 (cited above), which was widely distributed as "A. arizonica Gray," contains two things, *A. occidentalis occidentalis* and *A. occidentalis arizonica.* Asa Gray has noted this confusion on the sheet in the Gray Herbarium.

5. **Androsace elongata** subsp. **acuta** (Greene) comb. nov. based on

A. acuta Greene, Man. Bot. S. F. Bay. 238. 1894, this probably based on *Greene s. n.* 10 III 1889, from Livermore, Alameda Co., Calif. Type (in Herbarium Greeneanum 19323) studied for me by Dr. Theodor Just and compared with submitted collections from the region.

A. septentrionalis var. *subulifera* Gray, Synopt. Fl. N. Am. ed. 1, **2**:60. 1878, in part, as to paratype coll., *Parry and Lemmon* from San Bernardino, Calif. (Gray Herb.) examined.

A. asprella Greene, Pittonia **4**:150. 1900, based on *Thomas Howell,* 16 VII 1887, from Rogue River Valley, Ore. Photograph of type (Herb. Greeneanum) in Gray Herb. and isotypes (Univ. Calif. and Univ. Ore.) examined.

A. occidentalis var. *acuta* (Greene) Jepson, Man. Fl. Pls. Calif. 755. 1925, based on foregoing.

Slender annuals, 2-8 cm. high; scapes mostly 1-6, erect or lax and semi-decumbent; umbels 2-6-flowered, the pedicels filiform, lax, very unequal; leaves linear-lanceolate, attenuate-acute, 5-20 mm. long, entire or sparingly denticulate, the margins hispidulous; the herbage, including calyx lobes, puberulent; bracts of involucre narrowly-ovate, acute to acuminate; calyces narrowly campanulate to broadly so in fruit, the tube 5-ridged, the lobes subulate to acerose, pungently acute; corolla white, fading pink, small, included within calyx; capsule included within calyx.

Distribution: Oregon and California at widely scattered localities from the Rogue River Valley, Ore., the Siskiyou Mts., the Coast Ranges of the San Francisco Bay region, the southern Coast Ranges from San Luis Obispo Co. south to San Diego Co. and northern Baja California. Occurs principally at elevations of 1000-3000 (rarely 4500) feet altitude.

Representative collections examined. OREGON: Jackson Co.: Rogue R. Valley *(l.c.)*. CALIFORNIA: Siskiyou Co.: Greenhorn Creek, Siskiyou Mts., 1935, *Wheeler 3432;* Contra Costa Co.: Clayton, 1896, *Blasdale;* Alameda Co.: Berkeley Hills, 1902, *Tracy 1344;* San Joaquin Co.: Midway, 1932, *Mason 6820;* Fresno Co.: Alcade, 1893, *T. S. Brandege;* San Luis Obispo Co.: 35 mi. e. Paso Robles, 1926, *Munz 10169;* Kern Co.: Tehachapi Pass, 1925, *Munz 8938;* San Bernardino Co.: Crafton, *Parry and Lemmon 1184;* Los Angeles Co.: Puddingstone Canyon, San Dimas, 1937, *Munz 14937;* San Diego Co.: Warner's Hot Springs, 1913, *Eastwood 2594*. BAJA CALIFORNIA: 45 mi. se. Tecate, 1925, *Munz 9600*.

The differential characters which separate this American plant from the Eurasiatic *A. elongata* L. are so slight that it is here considered as a subspecies of the Old World plant. The examination of a series of European collections of *A. elongata* L. has shown that the only two constant morphological differences which distinguish it from the Pacific Coast plant are its slightly broader calyx lobes and its somewhat more vigorous habit. The Asiatic *A. engleri* Knuth, appears to be very closely related to *A. elongata* but I have seen no collections from this area. The occurrence of our plant on the geologically older land areas of the Pacific Coast may have significance in tracing its origin and affinities.

A. elongata acuta is readily distinguished from *A. occidentalis occidentalis* by its slender-subulate or acerose calyx lobes and its somewhat more delicate habit. Knuth (*l.c.*, p. 214) gives *A. acuta* as a synonym of *A. occidentalis* but he cites no Pacific Coast collection, so it seems doubtful that he had seen any material of authentic *A. acuta*.

The limital plant from Oregon described by Greene as *A. asprella* is indistinguishable from *A. elongata acuta*.

6. ANDROSACE SEPTENTRIONALIS L., Sp., Pl. 142. 1753, based on Lapland and Russian specimens.

A. arguta Greene, Pittonia **4**:148. 1900, based on W. G. Hay from Port Clarence, Bering Strait, 28 VI 1890. Photograph of type (Herb. Greeneanum) in Gray Herb. examined.

A. gormani Greene, Pittonia **4**:149. 1900, based on *Gorman 981* from Fort Selkirk, Yukon Valley, 24 V 1899. Photograph of type (Herb. Greeneanum) in Gray Herb. and isotypes (U. S. Natl. Herb.; Pomona Coll.) examined.

A. septentrionalis var. *Gormannii* [sic!] (Greene) Ostenfeld, Vidensk. Selsk. Skr. Mathem.-Naturv. Kl. (Oslo), **8**:61. fig. 21. 1910.

Annuals or short-lived perennials with a slightly thickened root crown; scapes few, one or more well-developed central ones, 4-25 cm. long, erect, bearing a scattered puberulence of simple and branched hairs with scattered rather obscure dark glandular hairs, or often becoming somewhat glabrate; pedicels slender, early glabrate, 15-25 on a well-developed scape, 2-5 cm. long, the central ones mostly erect, the lateral ones arched-ascending, forming a close "*Allium*-like" umbel; leaves rosulate, linear-lanceolate, entire or denticulate, sessile or only slightly narrowed at base, 1-3 cm. long, the margins and upper surfaces more or less covered with short, stiff, simple or branched hairs; bracts linear-lanceolate, acute; calyx-tube campanulate to broadly so in fruit, more or less contracted at base, 5-ridged, whitish or straw-colored, glabrous; the lobes often dark green, subulate-triangular, $1/4$-$1/3$ the length of the calyx; corolla white or pale pink, included within or slightly exceeding the calyx, the lobes obovate, obtuse; capsule globose, included; seeds 5-15, small.

Distribution: Widespread in boreal and arctic regions in Eurasia and the Arctic archipelago. Apparently very rare in the Canadian eastern Arctic[7] but becoming more common in the northern Canadian Rockies and Alaska.

Representative collection examined. GREENLAND: Thule, reg. of Etah, 1915, Ekblaw (Crockerland Expd. 615). GRINNELL LAND: H. M. S. Discovery, "Winter Quarters," [Discovery Bay, 1875-76], *H. C. Hart.* SASKATCHEWAN: Charlot Pt., Lake Athabaska, 1935, *Raup 6093.* ALBERTA: Fort Chipewyan, 1935, *Raup 6058*: Maligne Lake, 1908, *S. Brown 1241;* Bow River Valley, 1906, *S. Brown 54;* "Rky. Mts.," *Drummond.* B. C.: Cairn Mt., Marble Mts., 1938, *J. W. Thompson 256.* YUKON: Upper Bonanza, 1901, *MacLean;* Dawson slide, Dawson, 1914, *Eastwood 107.* ALASKA: Mt. McKinley Natl. Park, 1937, *Scamman 687;* Port Clarence, Bering Strait, 1931, *Mason s. n.*

The North American specimens of *A. septentrionalis*, as compared with European, vary considerably in degree of puberulence, glandulosity, and compactness of umbels, but there is no firm morphological basis for considering them as distinct. They are perhaps best regarded as variable populations of a species whose evolutionary development has not progressed sufficiently far enough to mark them as distinct entities.

This widespread northern species is considered to be close to the ancestral prototype for the subspecies discussed below. These subspecies appear to represent divergent populations of this more northern, perhaps preglacial ancestor. They have progressed to a point in their evolution so as to be recognized as morphologically discrete units but not to a point as to prevent occasional genetic intermingling and the occurrence of intermediate forms among them. The reasons for considering *A. septentrionalis* as a progenitor for these subspecies are: (1) its close morphological homogeneity, (2) the possession of

7 Cf. Polunin, N. Botany of the Canadian eastern Arctic, pt. I: 320. 1940. (Nat. Mus. Can. Bull. **92**, Biol. Ser. **24**).

certain characters which seem to mark it as primitive, such as, (a) a single well-developed scape, often with a few scapes of weaker development, (b) compact, "*Allium*-like" umbels, and (c) herbage with minute, dark, glandular hairs, and (3) its northern distribution.

Both *A. arguta* Greene and *A. gormani* Greene were based on young plants of *A. septentrionalis* in which the pedicels had not yet reached their full length, thus making the umbels appear unusually dense and subcapitate.

6a. ANDROSACE SEPTENTRIONALIS GLANDULOSA (Woot. & Standl.) St. John, Victoria Memorial Mus. Memoir **126**:47. 1922, *pro var. sed sensu emendo*, based on:

A. glandulosa Woot. & Standl., Bull. Torr. Club **34**:519. 1907, this based on *E. O. Wooton* from Middle Fork Rio Gila, Mogollon Mts., Socorro Co., N. Mex., 5 VIII 1900 (U. S. Natl. Herb.) examined.

Similar in habit and morphology to *A. septentrionalis septentrionalis*, but differing in having both more abundant reddish-brown glandular hairs and persistent simple and branched hairs; scapes 10-30 (or 35) cm. high with pedicels 2-7 cm. long, forming a somewhat compact umbel.

Distribution: Mountains of Colorado, New Mexico and Arizona at elevations of 7000-9000 feet altitude.

Representative collections examined. COLORADO: Clear Creek Co.: Georgetown, 1878, *M. E. Jones;* Park Co.: Como, 1895, [Crandall?]; Las Animas Co.: Dillon Canyon, Trinidad, 1892, without collector, *no. 980;* Mineral Co.: Wason, 1937, *B. K. Stewart 637;* Chaffee Co.: North Cottonwood Creek, 6 mi. w. Buena Vista, 1936, *Rollins 1383.* NEW MEXICO: Colfax Co.: 7.5 mi. nw. Dawson, 1941, *C. T. Robbins 570;* Rio Arriba Co.: Jarita Mesa, Carson Forest, 1924, *Eggleston 20514;* San Miguel Co.: Pecos Valley, Santa Fe Forest, 1924, *Eggleston 19999;* Catron Co.: Luna, Datil Forest, 1924, *Eggleston 20248.* ARIZONA: Co. undet.: "Open flats, alpine," 1912, *Goodding 1260;* Coconino Co.: Flagstaff, 1898, *Mac Dougal 151;* Flagstaff, 1907, *Thornber;* Apache Co.: Chuska Mts., Sonsela Butte, Southern Navajo Res., 1934, *Helm 35.*

The following collections appear to be intermediate between this subspecies and *A. septentrionalis subulifera*: COLORADO: Teller Co.: Divide, 1920, *Clokey 3829;* Mineral Co.: Wason, 1937, *Ramaley 16219;* Archuleta Co.: Piedra, 1924, *Schmoll* 1208.

True *A. septentrionalis* is not known to occur within the borders of the United States proper and this subspecies which has often been confused with it is the nearest approach to the typical phase.

6b. ANDROSACE SEPTENTRIONALIS ROBUSTA St. John, Victoria Memorial Mus. Memoir **126**:48. 1922, *pro var. sed sensu emendo*, based on *St. John 90814* from Ile. Ste. Genevieve, Quebec, 29 VI 1915. Type in Can. Natl. Herb. Topotype: *St. John 90816* (Can. Natl. Herb.) and isotype (Gray Herb.) examined.

This plant is similar in habit and morphology to *A. septentrionalis septentrionalis* but differs in the following features: plants glabrous, or base of scapes and leaves scabrous with short, simple and branched hairs; scapes and pedicels often stout, thickened; the pedicels often strongly divergent or erect

and arched-ascending, tending toward a loosely compact umbel; calyx-tube broadly campanulate to subglobose in fruit; capsule commonly surpassing calyx-tube.

Distribution: Calcareous cliffs and beaches along the Gulf of St. Lawrence and north to Hudson Bay. Rare.

Representative collections examined. QUEBEC: Mingan Isls.: Grande Is., 1925, *Marie-Victorin 27274;* Quin Is., 1926, *Marie-Victorin 27272;* Gulf of Saint Lawrence, w. Marten R., 1922, *Fernald & Pease 25231.* KEEWATIN DISTRICT: n. Cape Jones, Hudson Bay, 1899, *Low 63247.* MANITOBA: Churchill, Hudson Bay, 1910, *Macoun 79387.*

The isolated occurrence of this subspecies in an area supposedly strongly subjected to the effects of Pleistocene glaciation suggests that this plant may have persisted there on nunataks throughout the period of glaciation, but meanwhile became reduced and modified from its ancestral population. It is interesting to note that several collections of *A. septentrionalis septentrionalis* from the Canadian Rockies bear a very close resemblance to this eastern subspecies. Such collections as *S. Brown 1002* and *1241, Butters & Holway 14,* and *Raup 3007* (Gray Herb.), all from Alberta, possess the general habit of *A. septentrionalis robusta* including its broadly campanulate or sub-globose calyx-tube and its exserted capsule. The occurrence of species of Western Cordilleran affinities in the flora of the Gulf of St. Lawrence has frequently been reported by botanists and this subspecies appears to show such a relationship.

A collection from Newfoundland (Tucker's Head, Bonne Bay, 1929, *Fernald et al. 1954,* Gray Herb.), which consists of a single, small fruiting specimen and a sterile rosette, may possibly belong to this subspecies, but is here considered as typical *A. septentrionalis.* Fernald reports[8] these specimens as the only ones seen in Newfoundland, so it appears that there they represent a true relict population.

St. John has recently, but mistakenly, considered[9] this subspecies as var. *subulifera* Gray and several sheets in the Gray Herbarium have been so annotated. These two forms, however, are quite distinct, both in morphology and distribution.

6c. ANDROSACE SEPTENTRIONALIS SUBULIFERA Gray, Syn. Fl. N. Am. 2:60. 1878, *pro var. sed sensu emendo,* based on *H. G. French* from Lake Ranch near "Boulder City" (Boulder), Colo. (this station not identified but without doubt in the Front Range west of Boulder). Type (Gray Herb.) examined but paratype is *A. elongata* ssp. *acuta* (*q.v.*)!

A. diffusa Small, Bull. Torr. Club **25**:318. 1898, based on *Thos. Hogg* coll. from Colorado, *sine loco.* (Exact loc. not determined.) Type (Columbia Coll. Herb.) at N. Y. Bot. Gard. examined. (See Fig. 6).

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8 Fernald, M. L. Recent Discoveries in the Newfoundland Flora. Rhodora **35**:96, 1933.

9 St. John in Polunin, N. *l.c.*

A. pinetorum Greene, Pittonia **4**:149. 1900, based on *C. F. Baker 516* from Grahams Park, [n. e. La Plata Co.], Rio de los Pinos, Colo., 12 V 1899. Four isotypes examined.

Primula pinetorum (Greene) Derganc, Allgem. Bot. Zeit. **10**:110. 1904.

Primula septentrionalis var. *subulifera* (Gray) Derganc, Allgem. Bot. Zeit. **10**:110. 1904.

A. septentrionalis var. *diffusa* (Small) Knuth, *op. cit.*, p. 215. 1905.

A. septentrionalis var. *pinetorum* (Greene) Knuth, *op. cit.* p. 215. 1905.

A. subulifera (Gray) Rydb., Bull. Torr. Club, **33**:148. 1906.

Amadea diffusa (Small) Lunell, Am. Midland Nat. **4**:504. 1916.

Plants annual, essentially glabrous except for a minute puberulence at base of scapes and on leaves; leaves lanceolate-oblanceolate, denticulate towards apex, slightly narrowed at base, 1-3 (or 4) cm. long; scapes several, of equal development, 7-25 cm. high, somewhat slender, erect or arched-ascending; bracts of involucre slender-subulate to acerose; pedicels 5-15 (or more), filiform, 3-10 cm. long, (occasionally short and more robust), central ones erect or arched-ascending, lateral ones often spreading widely forming loosely compact or diffuse umbels; calyces narrowly campanulate to campanulate in fruit, 5-ridged; the lobes slightly keeled, slender subulate to acerose, $^1/_4$-$^1/_3$ the length of the calyx.

Distribution: Mountains of the central Rocky Mts., principally in Colo., south to N. M. and Ariz. and north to Wyo. and B. C. In wooded areas mostly at elevations from 6000-8500 ft. altitude.

Representative collections examined. COLORADO: Boulder Co.: Kosslers Lake (Reservoir), 5 mi. w. Boulder, 1941, *G. T. Robbins 445;* Blue Bird Mine, 1905, *Ramaley 1240;* Larimer Co.: Estes Park, 1904; *W. S. Cooper 270;* Summit Co.: Breckenridge, 1871, *T. S. Brandegee 161;* Clear Creek Co.: Headwaters of Clear Creek, 1861, *Parry 313;* Silver Plume, 1895, *Shear 3254;* El Paso Co.: vic. Pikes Peak, 1896, *Biltmore Herb. No. 950a;* Las Animas Co.: Berwind, 1900, *Archibald 238;* Saguache Co.: Crestone, 1928, *Ramaley 12088;* Alamosa Co.: Mosca Gulch, 1940, *Ramaley 17093;* Archuleta Co.: Pagosa Springs, 1921, *Bethel, Willey & Clokey 4234;* Mineral Co.: Wason, 1939, *B. K. Stewart 411;* San Juan Co.: Silverton, 1937, *Ramaley 16141;* La Plata Co.: Los Pinos (Bayfield), 1899, *C. F. Baker 515;* Montezuma Co.: Mancos, 1898, *C. F. Baker et al. 26;* San Miguel Co.: Norwood Hill, 1912, *Walker 501;* Montrose Co.: Naturita, 1914, *Payson 297;* Routt Co.: Steamboat Springs, 1903, *Osterhout 2786;* Grand Co.: Kremmling, 1915, *Osterhout 5220;* Gunnison Co.: Cebolla, 1912, *Payson 42;* Huerfano Co.: Turkey Creek, 1900, *Rydberg & Vreeland 5771.* NEW MEXICO: Colfax Co.: Raton Pass, 1941, *G. T. Robbins 604;* Bernalillo Co.: Sandia Mts., 1884, *M. E. Jones.* ARIZONA: Apache Co.: Luka-Chukai Mts., 1936, *Goodman & Payson 2903.* WYOMING: Albany Co.: Pole Creek, 1895, *A. Nelson 1332.* B. C.: Yoho Park, 1927, *Ulke 233.*

The following collections appear to be intermediate between this subspecies and *A. septentrionalis puberulenta:* COLORADO: Boulder Co.: Eldora, 1919, *Payson 1503;* Jefferson Co.: Golden, 1905, *Bailar;* Routt Co.: Little Columbine Lake, 1935, *Johnson 308;* Park Co.: Grant, 1904, *Huestis;* Lake Co.: Twin Lakes, 1903, *Juday;* El Paso Co.: Palmer Lake, 1941, *G. T. Robbins 461;* Ouray Co.: Ouray, 1920, *A. Nelson 9841.*

The type collection of this subspecies consists of a single specimen which is somewhat more slender in all its parts than is usual and probably represents a plant that grew in deep shade. Gray's description of this plant mentions only the subulate calyx lobes but he was perhaps also impressed by the long, slender

scapes and pedicels. A series of sheets of this subspecies from the area of the type locality (cf. *G. T. Robbins 765* from Bear Canyon) made late in the season and from a variety of sun and shade exposures shows, at least among the shade plants, this tendency toward a more slender habit.

The type of *A. diffusa* Small has a lower and more diffuse growth habit with many more scapes and pedicels than is typical of the subspecies (see Fig. 6). I have seen the following collections which match the type specimen of *A. diffusa,* all of them from Colorado: *Crandall 978* from mts. betw. Steeles and Little Beaver, (Larimer Co.), 1896; *C. C. Parry* in 1872, *sine loco,* (probably Clear Creek Co.); *Patterson 98,* in part, from mountain sides near Georgetown, (Clear Creek Co.), 1885; and *Ramaley et al., 3729,* from Ward, (Boulder Co.), 1907. These collections are from a rather limited area in northern Colorado where the typical phase of the subspecies is common. They seem to form a transitional series from plants of the taller, less diffuse habit to those which are shorter and more diffuse. The diffuse growth habit may be the result of an adaptation to altitude since the collections cited above appear to have been made at elevations exceeding 8000 feet, which marks the upper altitudinal limits of the range of the subspecies.

St. John's citation (*l.c.,* p. 50) of specimens includes plants referable to the typical phase of *A. septentrionalis subulifera* and still many others to be considered as *A. septentrionalis puberulenta. A. diffusa* has been cited by many authors as the commonest and most widespread species (or variety) in our area, a statement which is rather more applicable to *A. septentrionalis puberulenta.*

A. pinetorum Greene, as St. John has indicated (*l.c.,* p. 49), is based on early season specimens of *A. septentrionalis subulifera.*

6d. ANDROSACE SEPTENTRIONALIS SUBUMBELLATA A. Nels., Bull. Wyo. Exp. Sta. 28:149. 1896, based on *A. Nelson 998* from Union Pass, Fremont Co., Wyo., 13 VIII 1894. Type (Rocky Mt. Herb.) examined and two isotypes examined.

A. subumbellata (A. Nels.) Small, Bull. Torr. Club **25**:319. 1898.

Plants annual or weak perennial, often tufted, with a slightly thickened root crown; leaves linear-lanceolate, entire or sparingly denticulate towards apex, 5-20 mm. long, margin and upper surface minutely puberulent; scapes dwarfed, 1-3 cm. high, (entire plant not exceeding 5 cm. in height), appearing acaulescent in some smaller plants, erect or spreading, glabrous or with scattered puberulence towards base; bracts of involucre narrowly lanceolate, acute to acuminate; pedicels 2-7 (rarely more), short, stout, erect or spreading widely, unequal, glabrous; calyx campanulate to subglobose-campanulate in fruit, 5-ridged; the lobes $^1/_4$ (or $^1/_3$) the length of the tube, faintly keeled, narrowly triangular, acute; corolla white, fading pink; the lobes often surpassing or at least equalling the calyx; capsule included.

Distribution: High mountains from central Colo., ne. Utah and Nev., north to Wyo., Mont., Idaho, Alta., B. C., south to Ore. and Calif. Princi-

pally at elevations of 10,000-13,000 or 14,200 feet altitude in the southern part of its range and from 7000 to 10,000 ft. in the northern part of its range.

Representative collections examined. COLORADO: Boulder-Grand Cos.: Corona, 1919, *Munz 3005;* Rollins Pass, 1907, *Ramaley & Robbins 3323;* Clear Creek Co. (?): Gray's Peak, 1872, *A. Gray; sine loco, Parry 313a;* Park Co.: Boreas, 1904, *Huestis;* Larimer Co.: Pingree Park, 1924, *McCarty 26;* Jackson Co.: w. of Cameron Pass, 1894, *Crandall 1144;* Custer Co.: Lake of the Clouds, Sangre de Cristo Range, 1888, *Demetrio;* Lake Co.: Independence Pass, 1936, *Christ & Ward 2369;* Ouray Co.: Ouray, 1915, *Osterhout 5372.* UTAH: Duchesne Co.: Mt. Emmons, 1933, *Hermann 4951;* Summit Co.: near La Motte Peak, 1926, *Payson 4903;* Utah Co.: Mt. Timpanogos, 1926, *Garrett 3560;* Co. undet.: Bald Mt., Uinta Mts., 1911, *Mrs. J. Clemens.* NEVADA: Elko Co.: e. Humboldt Mts. [i.e. Ruby Mts.], 1868, *Watson 753;* White Pine Co.: Above Lake Stella, Snake Range, 1941, *Maguire 21138.* WYOMING: Albany Co.: Medicine Bow Mts., 1900, *A. Nelson 7898;* Johnson Co.: Powder River Pass, Big Horn Mts., 1935, *L. Williams 2338;* Park Co.: Beartooth Lake, Shoshone Natl. For., 1937, *L. Williams 3575;* Yellowstone Natl. Park: Dunraven Peak, 1899, *A. & E. Nelson 6682;* Sublette Co.: Piney Mt., 25 mi. w. Big Piney, 1922, *Payson 2687;* Lincoln Co.: Red Mt., ne. Smoot, 1923, *Payson & Armstrong 3646.* MONTANA: Madison Co.: Old Hollowtop, near Pony, 1897, *Rydberg & Bessey 4680;* Glacier Natl. Park: Sperry Glacier, 1909, *M. E. Jones.* ALBERTA: Banff, 1915, Ex. Herb. F. W. Hunnewell, 2nd., *No. 3794;* Maligne Lake, 1908, *S. Brown 1263.* B. C.: Heights above Carbonate 'Draw,' Selkirk Range, 1904, *Shaw 306;* Yoho Natl. Park, Lake McArthur, 1937, *Rose 37508;* Bluster Mt., Marble Mts., 1938, *Thompson 438.* OREGON: Wallowa Co.: Subalpine ridges of Wallowa Mts. near the lake [Wallowa Lake?], 1899, *Cusick 2269;* Aneroid Lake, 7 mi. s. Wallowa Lake, 1936, *Rose 36603.* CALIFORNIA: Mono Co.: Mono Pass, 1907, *Eastwood 537;* White Mts., 1886, *Shockley 452;* Tuolumne Co.: Mt. Dana, 1938, *Howell 14545;* San Bernardino Co.: San Gorgonio Mt., 1906, *Hall 7647.*

The following collections appear to be intermediate between this subspecies and *A. septentrionalis puberulenta:* COLORADO: Larimer Co.: *sine loco,* alt. 11,500 ft., *C. F. Baker;* Pitkin Co.: near Capitol Peak, 1938, *Penland 1518;* 10 mi. w. Independence Pass, 1938, *Hitchcock et al., 4000;* Mineral Co.: Wolf Creek Pass, San Juan Mts., 1934, *McKelvey 4759;* Hinsdale Co.: Carson, 1901, *C. F. Baker 300.* WYOMING: Albany Co.: Laramie Hills, 1896, *A. Nelson 1901;* Fremont Co.: 10 mi. ne. South Pass City, 1939, *Craig 3585;* Uinta Co.: Cumberland, 1907, *A. Nelson 9023;* Yellowstone Natl. Park: Mt. Washburn, 1932, *Maguire 1196.* UTAH: Cache Co.: Mt. Naomi, Bear River Range, 1936, *Maguire et al., 14151;* Summit Co.: Henrys Fork Lake, Henrys Fork Basin, Uinta Mts., 1936, *Maguire et al. 14387.*

The California plants referred to this subspecies are somewhat more puberulent on the scapes and have a more deeply-incised calyx-tube than is typical. They bear close resemblance to the alpine phase of *A. septentrionalis puberulenta.*

6e. ANDROSACE SEPTENTRIONALIS PUBERULENTA (Rydb.) Knuth, *l.c.*, p. 216. 1905, *pro var. sed sensu emendo,* based on:

A. puberulenta Rydb., Bull. Torr. Club **30**:260. 1903, this based on *Rydberg & Vreeland 5772,* Veta Pass, Huerfano Co., Colo., (N. Y. Bot. Gard.) examined.

Amadea puberulenta (Rydb.) Lunell, Am. Midland Nat. **4**:504. 1916.

Plants annual or alpine phase weak perennial, puberulent throughout, often including calyx lobes; leaves linear to lanceolate-oblanceolate, 1-3 (or 4) cm. long, denticulate or sparingly so at apex, slightly narrowed below, margins and upper surfaces finely puberulent, appearing scaberulous; well-developed scapes mostly 3-8, with often many weak supplementary ones, erect or spread-

ing widely and unevenly, unequal, more or less densely puberulent or sometimes nearly glabrous; pedicels mostly erect at flowering, often spreading widely and irregularly in age, more or less puberulent, unequal, forming very diffuse umbels; calyces narrowly campanulate (or vase-shaped) to broadly campanulate (or turbinate) in fruit, prominently 5-ridged; the lobes more or less keeled, subulate to narrowly lanceolate or broad and foliaceous in fruit; corolla white, fading pink, its lobes shorter than or equalling the calyx; capsule included.

Distribution: Central and southern Rocky Mountains (Colo., N. M., Ariz.) north to the Dakotas, Sask., Alta. and B. C. Occupies a wide range of altitude extending from the foothills to the alpine zone.

Representative collections examined. COLORADO: Larimer Co.: *sine loco*, 1895, *C. F. Baker* (Patterson no. 6733); Grand Co.: Granby, 1905, *Bethel;* Boulder Co.: Pactolus, 1915, *Ramaley 10494;* Gilpin Co.: Tolland, 1917, *Hall 10380;* Jackson Co.: Rabbit Ears Pass, 1939, *Rose 39300;* Garfield Co.: Trapper's Lake, 1937, *Johnson 639;* Summit Co.: Breckenridge, 1896, *Holzinger 39;* Lake Co.: Leadville, 1918, *Eastwood 7151;* Ouray Co.: Ouray, Yankee Boy Basin, 1915, *Osterhout 5325;* Eagle Co.: Tennessee Pass, 1941, *Killip 36431;* El Paso Co.: Gentian Ridge, 1901, *Clements 292;* Las Animas Co.: Monument Lake, 1941, *G. T. Robbins 557;* Huerfano Co.: Iron Mt., 1900, *Rydberg & Vreeland 5773;* Hinsdale Co.: Carson, 1901, *C. F. Baker 300;* Mineral Co.: Wagon Wheel Gap, 1939, *Stewart 105;* San Juan Co.: Ice Lake Basin, San Juan Mts. near Silverton, 1934, *Penland 1059;* San Miguel Co.: Dallas Divide, 1917, *Payson 1006;* Montezuma Co.: Mancos, 1898, *C. F. Baker et al. 144;* Mesa-Delta Cos.: Grand Mesa, 1936, *Ramaley 15467.* NEW MEXICO: Santa Fe Co.: Santa Fe Canyon, 1897, *Heller 3528;* San Miguel Co.: Grass Mt., Pecos River Natl. Forest, 1908, *Standley 4141;* Catron Co.: Mogollon Mts., 1903, *Metcalfe 341;* Otero Co.: Cloudcroft, Lincoln Forest, 1918, *Eggleston 14525;* Valencia Co.: Mt. Taylor, San Mateo Mts., Manzano Forest, 1923, *Eggleston 18692;* Socorro Co.: Black Canyon, Diamond Bar Range, Gila Forest, 1920, *Eggleston 16975;* Rio Arriba Co.: Largo Canyon near Reserve [Jicarilla Apache Res.], 1932, *Castetter 1401.* ARIZONA: Cochise Co.: Wickershams Cabin, Huachuca Mts., 1909, *Goodding 368;* Pima Co. (?): Santa Catalina Mts., 1881, *Lemmon 230;* Greenlee Co.: White Mts., 7 mi. s. Hannigan Meadows, 1927, *Goddard 667;* Yavapai Co.: Senator Mine, Prescott reg., 1929, *Eastwood 17653;* Coconino Co.: Kaibab Natl. Forest, 1934, *McKelvey 4396;* Grand Canyon Natl. Park, 1933, *Eastwood & Howell;* San Francisco Mt., 1938, *Little 4729;* Graham Co.: Pinaleno (Graham Mts.), 1935, *Maguire 12020;* Apache Co.: Thomas Peak [also Baldy Peak], White Mts., 1912, *Goodding 1133.* NEVADA: Clark Co.: Hidden Forest, Sheep Mts., 1940, *Alexander & Kellogg 1546;* Charleston Mts., 1926, *Jaeger;* White Pine Co.: Duck Creek, Schell Creek Mts., 1924, *M. E. Jones;* Elko Co.: Island Lake, Ruby Mts., 1940, *Munz 16244.*

UTAH: San Juan Co.: Elk Ridge, Abajo Mts., 1932, *Maguire & Redd 2015;* Grand Co.: La Sal Mts., 1924, *Payson 4084;* Garfield-Kane Cos.: Bryce Canyon, 1933, *Eastwood & Howell 762;* Iron Co.: Cedar Breaks, 1927, *Peirson 7517;* Piute Co.: Marysvale, 1894, *M. E. Jones 5365;* Sevier Co.: Summit of divide betw. Fish Lake and Salina Canyon, 1930, *Keck 667;* Uintah Co.: Dyer Mine, Uintah Mts., 1902, *Goodding 1250;* Duchesne Co.: Big Park, Uinta River Canyon, 1933, *Graham 8032;* Daggett Co.: Uintah Mts., 1932, *L. Williams 555;* Salt Lake Co.: Fort Douglas, 1910, *Mrs. J. Clemens;* Beaver Co.: Big Flat Ranger Sta., Tushar Mts., Fillmore Natl. Forest, 1914, *Eggleston 10487.* WYOMING: Albany Co.: Horse Creek, 1894, *A. Nelson 194;* Teton Co.: Teton Forest Res., 1897, *T. S. Brandegee;* Yellowstone Natl. Park: Glen Creek, 1899, *A. & E. Nelson 5609;* Washakie Co.: Tensleep Creek Canyon, Big Horn Mts., 1936, *L. Williams 3162;* Sublette Co.: Saltlick Mt., ne. Kendall, *Payson 2974;* Uinta Co.: Evanston, 1897, *A. Nelson 2988;* Big Horn Co.: Powder River, 1901, *A. Nelson 319.* IDAHO: Teton Co.: Victor, 1924, *A. Nelson 10058;* Bonneville Co.: Caribou Mt., 1923, *Payson & Armstrong 3529;* Clark Co.:

Dairy Creek, ne. Spencer, 1939, *Cronquist 1351;* Blaine Co.: Boulder Creek, Sawtooth Natl. For., 1937, *J. W. Thompson 14144;* Franklin Co. (?): Bear River range, sw. corner Franklin Basin, 1910, *C. P. Smith 2299;* Custer Co.: Yankee Fork, 1935, *A. D. Smith 26.* MONTANA: Gallatin Co.: Bracket Creek, 1901, *W. W. Jones;* Park Co.: Shields River above Wilsall, 1916, *Suksdorf 122;* Beaverhead Co.: Lima, 1908, *M. E. Jones;* Powell Co.: 2 mi. nw. Ovando, near Dick Creek, 1933, *C. L. Hitchcock 1598;* Glacier Natl. Park: Blackfoot Glacier, 1909, *M. E. Jones;* Sheridan Co.: Westby, 1927, *Larsen 14.* NORTH DAKOTA: Benson Co.: Leeds, 1900, *Lunell.* SOUTH DAKOTA: Pennington Co.: Deerfield, 1929, *E. J. Palmer 37486;* Lawrence Co.: Boulder Creek Park, 6 mi. e. Deadwood, 1927, *Hayward 1020;* Custer Co.: Buckhorn Mt., Custer, 1924, *McIntosh 173.* SASKATCHEWAN: Lipton, 1911, *Clokey 1815.* ALBERTA: Rosedale, 1915, *Moodie 832;* Lesser Slave Lake, 1903, *Macoun 61246.* B. C.: Dawson Creek, 1932, *Raup & Abbe 3523.*

This subspecies has been referred to *A. diffusa* Small in most manuals. Although the degree of puberulence varies considerably throughout its range, it is the most useful character for distinguishing this from related subspecies. The apparent frequent intergradation (possibly due to natural hybridization) of *puberulenta,* particularly with *subulifera* and *subumbellata,* has undoubtedly been responsible for a considerable amount of the confusion in this subspecies.

This subspecies, extending as it does over a wide range of altitude, is subject to a great deal of ecological variation in growth habit. Plants occurring in alpine regions remarkably simulate the dwarfed habit of *subumbellata* (*cf. G. T. Robbins 614*), but are readily distinguished from the latter by their more abundant puberulence and their more deeply-incised calyx lobes. Limital plants of the alpine regions of the San Francisco Mts. in Arizona, which have often been referred to *subumbellata,* possess the distinguishing characters of *puberulenta* but in somewhat reduced form.

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Notes on Wisconsin Grasses—IV

Leptoloma and Panicum

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Leptoloma and Panicum are so readily confused, and the characters used to separate them in manuals are so technical, that it may be well to begin by giving an easy means of distinguishing them:

Ligule a scale ..... *Leptoloma*
Ligule of hairs ..... *Panicum*

Leptoloma

LEPTOLOMA COGNATUM (Schultes) Chase probably was once a local and uncommon plant of sandstone outcrops in the Driftless Area, and sand terraces and islands along the Wisconsin and Mississippi Rivers. Prior to 1916, it had been collected only three times in Wisconsin. It has become abundant as a weedy invader of abandoned farm lands in the central sand area, and is becoming generally common on sandy soils in southern and southwestern Wisconsin. At Madison, where it was not collected until 1941, it is now abundant in parts of the University Arboretum. In general appearance it suggests *Panicum capillare,* but the panicle is more open and less branched, and the plants art tufted perennials instead of annuals.

Panicum

Panicum has long had a reputation as a troublesome and difficult genus. Some authors have felt compelled to describe numerous poorly defined species; others suggest that the whole genus, or at least the subgenus *Dichanthelium,* is an inextricable complex, containing no real species. The truth lies somewhere between. Some Panicums—in Wisconsin, the villain is *P. implicatum*—run to numerous forms which sometimes appear quite different, but which are connected by many intermediates and seem impossible to separate in any satisfactory manner. Others are uniform, distinct, and easily recognizable, and in Wisconsin, Panicum is remarkable for so large a genus in the high proportion of its species which belong to this class.

Much difficulty has resulted from attempts to follow standard treatments which, although they may be satisfactory in parts or for other regions, are often of no help in Wisconsin, and frequently are actually misleading. Much difficulty in the subgenus *Dichanthelium* has been due to attempts to work with autumnal collections, which are quite unsatisfactory for critical determination. Some of the most useful diagnostic characters—the nature of the pubescence, and the proportions of the primary culm leaves—are obscured on weatherbeaten plants, and on secondary branches are unlike those of the vernal culms, being much more similar between species than was the case earlier in

the year. There is often more difference in appearance between the vernal and autumnal phases of the same plant than between autumnal plants of different species. Since the latter have little to offer but unnecessary difficulty, the present study has been based almost exclusively on vernal specimens, and the key is intended for use with them alone.

In the list of species, references are given only for names not used in Hitchcock's *Manual* (1935), or used there in a different sense. Habitat and soil preferences are given for each species, and pH preferences are indicated if tests have been made in at least three localities, using a small Hellige-Truog colorimetric tester in the field. Probably in no case is soil acidity a limiting factor in distribution, though most of the species show distinct preferences and occur in abundance only under preferred conditions. The flowering dates given are those of the main flowering season; stragglers flowering earlier or later are by no means rare. Cited specimens are in the Herbarium of the University of Wisconsin unless otherwise indicated.

KEY TO THE WISCONSIN SPECIES OF PANICUM

1. Plants flowering twice, with terminal panicles in spring and early summer, and with lateral or basal panicles from axillary branches in summer and fall; panicles 2-12 cm. long; plants perennial, tufted, with basal rosette leaves shorter and proportionally broader than those of the culms.
   2. Blades of middle culm leaves 20 times or more as long as wide.
      3. Internodes glabrous or minutely pubescent.
         4. Longest pedicels (excluding terminal spikelets of the panicle and its main branches) less than 3 mm. long, most of them not longer than their spikelets; pedicels 0.2-2.8 mm. long, spikelets 2.6-3.3 mm. long....1. *P. perlongum*
         4. Longest pedicels (excluding terminal spikelets) more than 3 mm. long, many or most of them longer than their spikelets: pedicels 0.5-6.5 mm. long, spikelets 2.0-4.1 mm. long.
            5. Spikelets 3.0-4.1 mm. long, more or less beaked.
               6. Sheaths pilose .....2a. *P. depauperatum*
               6. Sheaths glabrous .....2b. *P. depauperatum* var. *psilophyllum*
            5. Spikelets 2.0-2.9 mm. long, not beaked.
               7. Sheaths pilose .....3a. *P. linearifolium*
               7. Sheaths glabrous .....3b. *P. linearifolium* var. *Werneri*
      3. Internodes pilose.
         8. Spikelets 2.0-2.2 mm. long; largest culm leaves 11-15 cm. long..... .....3 × 6. *P. linearifolium* × *P. praecocius*
         8. Spikelets 2.3-3.1 mm. long; largest culm leaves 5-8 cm. long..... .....12. *P. Wilcoxianum*
   2. Blades of middle culm leaves less than 20 times as long as wide.
      9. Spikelets less than 3 mm. long.
         10. Pubescence of the sheaths of a single type (excluding ciliation of sheath margins), or pubescence absent (hairs in some pubescent species grading to shorter on upper sheaths, or toward the summits of sheaths, but fine pubescence not present throughout a sheath, and long and short hairs not occurring intermixed).
            11. Spikelets 2.3-3.1 mm. long; middle culm leaves 15 times or more as long as wide.....12. *P. Wilcoxianum*

11. Spikelets 1.2-2.2 mm. long; middle culm leaves less than 15 times as long as wide.
    12. Ligules of upper culm leaves less than 1 mm. long.
        13. Uppermost leaf blades 1-5 mm. wide; plants flowering in late May and early June ..... 4. *P. dichotomum*
        13. Uppermost leaf blades 4.5-11 mm. wide; plants flowering in late June and early July..... 5. *P. boreale*
    12. Ligules of upper culm leaves more than 1 mm. long.
        14. Middle hairs of uppermost sheaths 3-5 mm. long, spreading at right angles, nearly uniform in length from base to summit of sheath ..... 6. *P. praecocius*
        14. Middle hairs of uppermost sheaths, if present, 0.2-2.2 mm. long, widely spreading or ascending, becoming shorter toward the summit of the sheath
            15. Largest leaf blades of flowering culms more than 5.2 cm. long or more than 5 mm. wide or both..... 7. *P. implicatum*
            15. Largest leaf blades of flowering culms not more than 5.2 cm. long nor more than 5 mm. wide.
                16. Blades of old basal rosette leaves 1-2 cm. long; blades of lowest culm leaves 1.5-3.0 cm. long; plants of various habitats throughout the state..... 7. *P. implicatum*
                16. Blades of old basal rosette leaves 2-3 cm. long; blades of lowest culm leaves 2.5-4.0 cm. long; plants of sandy lake shores, northwestern Wisconsin..... 8. *P. albemarlense*
10. Pubescence of the sheaths of two types: short hairs much like those of the spikelets (best seen on upper sheaths, often obscured by long hairs on lower sheaths), and long pilose hairs (best seen on lower sheaths, often not extending to uppermost sheaths), the two occurring intermixed, at least on middle sheaths.
    17. Spikelets 1.3-1.6 mm. long; blades of main culm leaves 2.5-5.5 cm. long by 2-4 mm. wide ..... 9. *P. meridionale*
    17. Spikelets 1.6-2.9 mm. long; largest culm leaves either more than 5.5 cm. long or more than 4 mm. wide or both.
        18. Spikelets 1.6-2.0 mm. long; leaf blades densely and finely pubescent beneath (very rarely glabrous)..... 10. *P. tsugetorum*
        18. Spikelets 2.0-2.9 mm. long; leaf blades pilose or both pilose and finely pubescent beneath ..... 11. *P. euchlamydeum*
9. Spikelets 3.0-4.5 mm. long
    19. Blades of middle culm leaves 15-20 times or more as long as wide..... 12. *P. Wilcoxianum*
    19. Blades of middle culm leaves less than 15 times as long as wide.
        20. Blades of middle culm leaves more than 7 times as long as wide.
            21. Lower internodes finely pubescent or pilose (sometimes sparsely so); uppermost leaf blades 3.5-11.5 cm. long by 6-12 mm. wide.
                22. Spikelets oblong to lanceolate in outline, 1.7-2.5 mm. longer than wide, 3.2-4.2 mm. long by 1.5-2.0 mm. wide..... 13. *P. Leibergii*
                22. Spikelets lanceolate-oval to suborbicular in outline, 0.6-1.6 mm. longer than wide, 3.0-3.6 mm. long by 1.6-2.3 mm. wide..... 14. *P. Scribnerianum*
            21. Lower internodes glabrous; uppermost leaf blades 9-16 cm. long by 10-20 mm. wide ..... 15. *P. xanthophysum*

20. Blades of middle culm leaves less than 7 times as long as wide.
23. Leaf blades 1.8-3.0 cm. wide, 7.5-15.0 cm. long.....16. *P. latifolium*
23. Leaf blades 0.6-1.5 cm wide, 3.0-8.5 cm. long.....14. *P. Scribnerianum*

1. Plants flowering once, in summer and fall, with terminal or both terminal and axillary panicles at once; panicles 5-40 cm. or more long; plants annual or perennial, solitary or tufted, without basal rosette leaves.
24. Plants without creeping rhizomes, annual; lower glume ¼-¾ as long as the upper.
25. Sheaths glabrous except at the throat.....17. *P. dichotomiflorum*
25. Sheaths pilose over the surface.
26. Spikelets 1.4-3.5 mm. long.
27. Internodes pilose.
28. Spikelets 1.9-3.3 mm. long, lower glumes 0.9-1.7 mm. long; axils of primary branches of the inflorescence pilose.....18. *P. capillare*
28. Spikelets 1.4-2.1 mm. long, lower glumes 0.4-0.9 mm. long; axils of primary branches of the inflorescence either glabrous or pilose.....19. *P. philadelphicum*
27. Internodes glabrous .....20. *P. flexile*
26. Spikelets 4.0-5.8 mm. long.....21. *P. miliaceum*
24. Plants with scaly creeping rhizomes, perennial; lower glume nearly or quite as long as the upper.....22. *P. virgatum*

I. DEPAUPERATUM GROUP

Low tufted plants 15-40 cm. tall, with long narrow leaves rather crowded toward the base of the plant; primary panicles at maturity exserted on long naked peduncles, secondary panicles confined to the base of the plant.

1. P. PERLONGUM Nash. Common on prairies and limestone bluffs, found less abundantly on sandy ground, preferring neutral to alkaline soils (pH 6.5-8.0); southern and western Wisconsin. Flowering in early and mid-June.

2a. P. DEPAUPERATUM Muhl. Frequent on sandstone bluffs and in open sandy ground, preferring acid to neutral soils (pH 5-7); southern and western Wisconsin. Flowering from mid-June to early July.

2b. P. DEPAUPERATUM var. PSILOPHYLLUM Fernald, Rhodora 23:193, 1921. Abundant in sandy soil, central and northern Wisconsin, rare southward on sandstone bluffs; preferring acid soils. Flowering from early June to early July.

3a. P. LINEARIFOLIUM Scribn. Sandy open ground or sandy borders of woods; frequent in northern Wisconsin, rare southward as far as Richland and Milwaukee Counties. Flowering from mid-June to early July.

P. linearifolium x *P. praecocius*. Soo Line Railroad right-of-way 1½ miles south of Rice Lake, Barron Co., *L. H. Shinners 4493*, July 4, 1942. Growing in sand, with the parents and intermediate in appearance between them: panicles and long spreading sheath hairs as in *P. praecocius*, long naked peduncles of the panicles and narrow elongate leaves more like those of *P. linearifolium*, spikelets 2.1 mm. long. A single clump found. Two other similar collections

are placed here, though in the absence of information concerning the accompanying species, it is not certain that the narrow-leaved parent was not some other member of the Depauperatum Group than *P. linearifolium*: Roadside bank, sandy soil, ½ mile east of Warrens, Monroe Co., *Shinners & Catenhusen 1843*, June 19, 1940. On moist edge of sandy bogs about 10 miles east of Westfield, Marquette Co., *S. C. Wadmond*, June 29, 1935 (in herb. S. C. Wadmond).

3b. P. LINEARIFOLIUM var. Werneri (Scribn.) Fernald, Rhodora 23:194, 1921. *P. Werneri* Scribn. Occasional in central and northern Wisconsin, sometimes growing with the species. Flowering in late June and early July.

II. DICHOTOMUM GROUP

Plants wholly glabrous, or occasionally the lower internodes and sheaths very sparsely pilose; ligules less than 1 mm. long.

4. P. DICHOTOMUM L. Woodlands, rare; known from a single collection: Fox Point, Lake Mendota, Madison, Dane Co., *J. T. Curtis*, May 21, 1941. Not previously reported from Wisconsin.

5. P. BOREALE Nash. Probably common in central and northern Wisconsin, though not much collected, rare southward; preferring somewhat damp acid soils (pH 5-6). Flowering from late June to mid-July. Usually a rather tall plant (40-70 cm.) with few, ample, glabrous, somewhat succulent leaves.

III. IMPLICATUM GROUP

Plants of low or medium height (15-50 cm.; rarely more in forms of *P. implicatum*), glabrous or more usually pubescent or pilose, with hairs essentially of one type; ligules more than 1 mm. long.

6. P. PRAECOCIUS H. & C. Prairies and oak openings, very common in southern and western Wisconsin, usually in silty or sandy loam, less often in sand, preferring neutral or alkaline soils (pH 6.5-8.0). Flowering in mid- and late June.

P. praecocius x *P. Scribnerianum*. A single specimen seen, from a sandy roadside north of Portage, Columbia Co.; see discussion of mass collection number 2, below.

7. P. IMPLICATUM Scribn., U. S. Dept. Agric. Div. Agrost. Bull. 11:43, July 20, 1898. Including *P. huachucae, P. lanuginosum, P. Lindheimeri, P. subvillosum*, and *P. tennesseense* of authors, as to plants of Wisconsin, at least in large part (see further discussion of these names in the list of excluded species and varieties, below).

The most widespread, abundant, variable, and the only really difficult species—or species complex—in Wisconsin, occurring in a variety of habitats and showing no decided preference with regard to soil acidity. The most common form has pilose sheaths and blades, and small spikelets 1.3-1.6 mm. long.

A much less common form has sheaths and blades nearly or quite glabrous and somewhat succulent, and larger spikelets 1.6-2.0 mm. long. Less common than either of these are two additional forms having the same characters in reverse combination. Many specimens fall on the border lines, and cannot be assigned to any of these four. Forms can also be distinguished differing in other characters: the size of the upper leaf blades, the pubescence of the lower surfaces of the leaves as compared with the upper, the presence or absence of long hairs in the panicle or its stalk, and the pilosity of the internodes. Each of these characters seems to behave as if it were largely independent of the rest; they show no obvious consistency in their occurrence, and no distinctive geographic distribution in the state. Yet from the remarkable uniformity of the plants in any one locality, as shown by mass collections, it would seem that definite races do occur. For the present, no attempt is made to distinguish them or give them taxonomic standing. The flowering period (varying somewhat between forms) is from mid-June to early July.

P. implicatum x *P. meridionale*. See discussion of mass collection number 3, from north of Mazomanie, Dane County. One herbarium specimen closely resembles certain of the Mazomanie plants, having the slender delicate stems of *P. meridionale*, but somewhat larger and coarser leaves and no distinct fine pubescence, though the hairs of the upper sheaths are uneven in length: Swale, Birch Lake, Montello, Marquette Co., *N. C. Fassett 19581*, June 20, 1938.

P. implicatum x *P. praecocius*. Known from three localities; see discussion of mass collections number 2, from north of Portage, Columbia County, and number 3, from north of Mazomanie, Dane County.

P. implicatum x *P. tsugetorum*. Andrae State Park, Sheboygan Co., *A. M. Fuller 375*, June 30, 1925. Duplicates in the Herbarium of the Milwaukee Public Museum are the glabrate extreme of *P. implicatum* which has been called *P. tennesseense* or *P. lanuginosum* var. *septentrionale*. All the specimens have the same general appearance, but those in the University of Wisconsin Herbarium are finely pubescent on the upper sheaths. *P. tsugetorum* is the only species having fine pubescence which is found in or near Sheboygan County.

8. P. ALBEMARLENSE Ashe. Sandy shores of glacial lakes in northwestern Wisconsin; flowering in late June. Known at present from a single vernal specimen: In sand, south shore of Devil's Lake, near the water's edge, pH 6.5, Webster, Burnett Co., *Shinners 4524*, July 6, 1942.

It is probable that *Panicum albemarlense* is not the correct name for this plant. Southeastern Coastal Plain specimen so labelled, loaned from the U. S. National Herbarium, do not appear to be identical. The Wisconsin plant is a close match for *Plantae Exsiccatae Grayanae* No. 311 from Saul's Pond, Brewster, Massachusetts, collected by M. L. Fernald and distributed as *P. albemarlense*. The Wisconsin plant does not have the secondary pubescence called for in Ashe's description (Jour. Elisha Mitchell Soc. **16**:84, 1899), which on the Massachusetts specimen is rather long and spreading; it is possible that when more material is available these two may prove to be varietally distinct.

The secondary pubescence in *P. meridionale* is minute and more or less appressed. In Wisconsin the two species are very dissimilar in appearance when seen growing, *P. meridionale* being much finer and more delicate; but much of the distinctness is lost in the herbarium. *P. albemarlense* also has a different aspect from *P. implicatum* when seen growing, but again herbarium specimens are very difficult to separate.

P. albemarlense x *P. implicatum*. Sandy ground, railroad right-of-way 1 mile south of Webster, Burnett Co., *Shinners 4541*, July 5, 1942. Placed here because of its general appearance, intermediate between that of the supposed parents as found about Webster. A single plant found, having the large basal rosette leaves and small stem leaves of *P. albemarlense*, but not growing on or very near a lake shore, a habitat to which that species was found to be restricted in two days' collecting in the area.

IV. EUCHLAMYDEUM GROUP

Plants of small to medium size, pilose and with fine pubescence in addition; ligules 0.5 mm. or more long.

9. P. MERIDIONALE Ashe. Frequent in sandy ground or on sandstone or igneous rock outcrops, central Wisconsin; preferring strongly acid soils (pH 4.5-5.5), often growing in a mat of mosses, particularly of *Polytrichum juniperinum*. Flowering from mid-June to early July. A delicate little species with slender stems 12-30 or rarely 40 cm. high, usually erect, but becoming sprawling or decumbent as the secondary branches become too heavy for the weak culms to support.

It is possible that true *P. meridionale* is not found in Wisconsin. Its occurrence on rock outcrops is abnormal in this region for a plant supposed to have come from the Coastal Plain. As in the case of the preceding species, the type is not at present available for study.

10. P. TSUGETORUM Nash. Very common in central and northern Wisconsin, rare southward; preferring acid to neutral sandy soils (pH 5.5-7.0). Flowering from mid-June to early July. It is possible that Fernald is correct in reducing this to synonymy under *P. columbianum*. Lacking familiarity with the latter plant as found in the east and not having seen its type, I prefer to retain *P. tsugetorum* for the present.

11. **P. euchlamydeum** sp. nov. *P. pseudopubescens* of Deam, Grasses of Indiana, p. 282, 1929; not *P. pseudopubescens* Nash.—Species subgeneris Dichanthelii, pubescentia duplici vestita, *P. tsugetorum* affinis, grandior, spiculis majoribus, (2.0-2.9 mm. longis). TYPE: Sandy slope, pH 7.5, 12 miles southeast of Adams, Adams Co., Wisconsin, *L. H. Shinners & C. G. Shaw 4415*, June 28, 1942 (in Herb. University of Wisconsin; duplicate in Gray Herb., U. S. Nat. Herb., Herb. University of Minnesota, and Herb. Milwaukee Public Museum).

Common in central and western Wisconsin and adjacent Minnesota; also found in the Indiana Dunes and on the eastern shore of Lake Michigan as far

north as Grand Traverse Bay, Traverse Co., Michigan. Prefers neutral to alkaline sand (pH 6.5-8.0). Flowering in mid- and late June.

This is the plant which, in company with misidentified *P. praecocius* and forms of *P. implicatum*, has been the basis for reports of *P. pseudopubescens*, *P. scoparioides*, and *P. villosissimum* from the Middle West. These species are all Coastal Plain plants with a single type of pubescence only, and are not found in Wisconsin.

V. LATIFOLIUM GROUP

Stout plants, with ample leaves and large spikelets (except *P. Wilcoxianum*).

12. P. WILCOXIANUM Vasey. Dry prairies and limestone bluffs, at present known from Jefferson, Dane, Iowa, and Columbia Counties, in south central Wisconsin, but probably occurring locally throughout the southwestern quarter of the state; preferring neutral or alkaline soils. Flowering in early and mid-June. Not previously reported from Wisconsin.

A low plant with narrow leaves, resembling the much more abundant *P. perlongum* in general appearance and habitat, and doubtless often overlooked on that account. In summer and fall the plants acquire a compact bushy appearance as the short secondary branches appear, often overtopping and concealing the primary panicles. This species is placed with the next following the treatment of Hitchcock and Chase; it is not entirely at home in any of the groups adopted here.

13. P. LEIBERGII (Vasey) Scribn. Prairies and oak openings rather common in central, southern, and western Wisconsin; preferring neutral or slightly alkaline sandy loam (pH 6.5-7.5). Flowering in mid- and late June. In the field much resembling *P. Scribnerianum*, but usually taller and with longer leaves. It is more restricted to slightly heavier soils, and shows little tendency to become a weedy invader of sandy waste ground, as does *P. Scribnerianum*.

14. P. SCRIBNERIANUM Nash. Prarires, oak openings, and sandy ground, very common in central, southern, and western Wisconsin; showing no decided preference with regard to soil acidity. Flowering in mid- and late June. A rather weedy plant, often abundant in abandoned fields and along roadsides. It is possible that Fernald is correct in reducing this to a variety of *P. oligan-thes*, but herbarium specimens alone do not offer sufficient basis for a decision, and I am not otherwise acquainted with the latter species.

15. P. XANTHOPHYSUM A. Gray. Sandy ground and open woods (especially of jack pine and red pine), becoming locally abundant on cutover land, central and northern Wisconsin. Flowering in late June and July.

16. P. LATIFOLIUM L. Common in deciduous woodland borders throughout the state, except in the northernmost counties. Preferring more or less sandy soils, slightly acid or neutral (pH 6-7). Flowering in late June and July.

VI. CAPILLARE GROUP

Annuals, mostly weedy; flowering in August and September.

17.P. DICHOTOMIFLORUM Michx. Becoming a common weed of waste ground in cities, about farms, and along railroads, in the southern third of the

state; adventive from farther south. First collected in Wisconsin in 1914; nearly all the present records date from within the past 15 years.

18. P. CAPILLARE L. An abundant weed in a variety of habitats throughout the state. For var. *occidentale* and a brief discussion of variations, see the list of excluded species and varieties, below.

19. P. PHILADELPHICUM Bernh. Including *P. Tuckermani* Fernald. Occasional, shores of lakes and streams, central and northern Wisconsin.

20. P. FLEXILE (Gattinger) Scribn. Locally abundant, peaty sedge meadows and low prairies, southeastern Wisconsin; preferring neutral or alkaline soils (pH 7-8). Not previously reported from Wisconsin; known at present from Racine, Walworth, Jefferson, and Waukesha Counties.

21. P. MILIACEUM L. Infrequently cultivated, and rarely appearing as a waif along roadsides and railroads and in waste places. First collected in Wisconsin in 1908; has been found growing wild in Milwaukee, Dane, Sheboygan, Rusk, Brown, and Marinette Counties.

VII. VIRGATUM GROUP

A tall perennial 60-120 cm. or more high, with ample panicles and scaly creeping rhizomes, forming clumps. Flowering mainly in August.

22. P. VIRGATUM L. Very common in prairies (especially low prairies) and sandy ground, native in the southern, central, and western parts of the state. Tends to be weedy, appearing in abandoned fields, along railroads and roadsides, and in waste ground; now extending into northern and eastern Wisconsin, and probably found in every county in the state. Variable in stature, foliage, and size and shape of panicle and spikelets, but never approaching any other Wisconsin species. For var. *cubense*, see the list of excluded species and varieties, below.

A Note on Mass Collections

The purpose of a taxonomic paper such as this is to record what Dobzhansky (1937, p. 304) has aptly called "empirically existing discontinuities, in materials to be classified." In order to test the dependability of certain characteristics relied upon as the best indicators of such discontinuities, two procedures may be followed. The ordinary procedure, and the one by which the present taxonomic treatment of the Wisconsin species of Panicum was largely worked out, is to examine as a large as possible a number of ordinary herbarium specimens. A further more intensive test may be made by mass collections, such as used by Fassett for both taxonomic and phytogeographic purposes (e.g., in *Rubus*, 1941). For the present study, a single complete flowering culm was taken at random from each of a number of plants of Panicum in places where one to four species of the troublesome Implicatum and Euchlamydeum groups were known to be growing, and the resulting specimens measured for the sizes of parts used in the key. The results of four such collections are tabulated below. The disparity in totals of measurements of spikelets and of upper sheath hairs is due to the omission in the tables for the latter of

plants with glabrous sheaths or with lower sheaths overlapping the upper by half way or more.

MASS COLLECTION 1: Hillside between Madison and Middleton, Dane Co.; field uncultivated for at least six years, covered by bluegrass sod, being invaded by prairie plants from the adjacent railroad right-of-way; sandy loam, pH 6.5. Four species of Panicum present: *P. perlongum, P. Scribnerianum, P. praecocius,* and *P. implicatum;* only the last two included in the mass collection.

TABLE 1.—Length of Spikelets of 56 Individuals (Mass Collection No. 1).

1.3 mm. — 14	1.8 mm. — 2
1.4 mm. — 14	1.9 mm. — 4
1.5 mm. — 7	2.0 mm. — 10
1.6 mm. — 0	2.1 mm. — 4
1.7 mm. — 0	2.2 mm. — 1

TABLE 2.—Length of Middle Hairs of Uppermost Sheaths of 36 Individuals (Mass Collection No. 2).

0.6 mm. — 2	1.6 mm. — 0	2.6 mm. — 0	3.6 mm. — 2
0.7 mm. — 2	1.7 mm. — 0	2.7 mm. — 0	3.7 mm. — 2
0.8 mm. — 2	1.8 mm. — 0	2.8 mm. — 0	3.8 mm. — 2
0.9 mm. — 4	1.9 mm. — 0	2.9 mm. — 0	3.9 mm. — 1
1.0 mm. — 5	2.0 mm. — 0	3.0 mm. — 0	4.0 mm. — 4
1.1 mm. — 2	2.1 mm. — 0	3.1 mm. — 0	4.1 mm. — 1
1.2 mm. — 1	2.2 mm. — 0	3.2 mm. — 0	4.2 mm. — 1
1.3 mm. — 1	2.3 mm. — 0	3.3 mm. — 0	4.3 mm. — 2
1.4 mm. — 0	2.4 mm. — 0	3.4 mm. — 0	4.4 mm. — 1
1.5 mm. — 0	2.5 mm. — 0	3.5 mm. — 0	4.5 mm. — 1

The plants with larger spikelets also had the longer sheath hairs. It is obvious that two groups are represented, with a complete "empirically existing discontinuity" between them.

MASS COLLECTION 2: Sandy roadside north of Portage, Columbia Co.; *Panicum Scribnerianum, P. praecocius,* and two forms of *P. implicatum* (pilose and glabrate) present, the first omitted from the mass collection.

TABLE 3.—Length of Spikelets of 43 Individuals (Mass collection No. 2).

1.4 mm. — 6	1.8 mm. — 6	2.2 mm. — 0
1.5 mm. — 1	1.9 mm. — 7	2.3 mm. — 0
1.6 mm. — 4	2.0 mm. — 10	2.4 mm. — 1
1.7 mm. — 5	2.1 mm. — 3	

TABLE 4.—Length of Middle Hairs of Uppermost Sheaths of 41 Individuals (Mass Collection No. 2).

0.7 mm. — 3	1.6 mm. — 0	2.5 mm. — 1	3.3 mm. — 2
0.8 mm. — 2	1.7 mm. — 0	2.6 mm. — 1	3.4 mm. — 1
0.9 mm. — 3	1.8 mm. — 0	2.7 mm. — 1	3.5 mm. — 2
1.0 mm. — 0	1.9 mm. — 0	2.8 mm. — 3	3.6 mm. — 2
1.1 mm. — 0	2.0 mm. — 1	2.9 mm. — 3	3.7 mm. — 0
1.2 mm. — 1	2.1 mm. — 1	3.0 mm. — 6	3.8 mm. — 0
1.3 mm. — 0	2.2 mm. — 1	3.1 mm. — 3	3.9 mm. — 0
1.4 mm. — 0	2.3 mm. — 2	3.2 mm. — 1	4.0 mm. — 1
1.5 mm. — 0	2.4 mm. — 0		

The single individual with spikelets 2.4 mm. long had sheath hairs only 2 mm. long, most of them with distinctly swollen bases. In appearance and proportions, the spikelets and foliage approach *P. Scribnerianum,* and the full herbarium specimen (*Shinners & Shaw 4360*) was identified as a hybrid of that species and *P. praecocius.*

The plants with long sheath hairs also had relatively large spikelets (1.6-2.1 mm. long). Those falling in the continuous series from 2.5 to 3.6 mm. in length of sheath hairs apparently form a single group, but they varied in abundance and degree of spread of hairs. According to measurements of ordinary herbarium specimens and of mass collections 1 and 3, the normal range in length of sheath hairs for *P. praecocius* is 3-5 mm. This collection, then, represents a population of which one portion is dominated by characteristics of *P. praecocius,* and is separated from the rest by a distinct gap in the length of sheath hairs, but which is not typical of *P. praecocius* as represented elsewhere and as it appears in the herbarium. Instead, its measurements show a decided displacement toward those of *P. implicatum.* The natural supposition is that a hybrid swarm is being produced, complicated by the presence of two forms of one parent, and the possible intrusion of a third into the mixture. In this instance the plants were growing along a disturbed roadside, precisely the sort of locality in which wild hybrids are most apt to be found (cf. Wiegand, 1935). Fortunately for the taxonomist, specimens showing a mixture of characters are not common; apart from mass collection 3, only one herbarium collection represented an apparent hybrid between *P. implicatum* and *P. praecocius.* This was found in "drier and less shaded parts of morainal pasture and tree zone, University Bay, Madison, Dane Co.," *J. R. Heddle 2T11,* July 9, 1909 (three sheets in Herb. Milwaukee Public Museum, and a fourth having same date and locality but marked "tree zone on moraini island").

MASS COLLECTION 3: Sand island in Wisconsin River bottoms north of Mazomanie, Dane Co. *Panicum Scribnerianum, P. meridionale, P. implicatum,* and *P. praecocius* present, the first omitted from the mass collection.

TABLE 5.—Length of Spikelets of 84 Individuals (Mass Collection No. 3).

1.2 mm. — 5	1.5 mm. — 5	1.8 mm. — 2
1.3 mm. — 47	1.6 mm. — 4	1.9 mm. — 2
1.4 mm. — 15	1.7 mm. — 1	2.0 mm. — 3

Three species do not stand out in this table; the specimens must be separated on some other basis than spikelet length. Seven differed from the rest in having fine secondary pubescence on the upper sheaths; their spikelet measurements are given in Table 6.

TABLE 6.—Length of Spikelets of 7 Individuals With Finer Pubescence on Upper Sheaths (Mass Collection No. 3).

1.3 mm. — 4
1.4 mm. — 2
1.5 mm. — 1

These seven form a well-knit group, clearly referable to the one species *Panicum meridionale.* The remaining specimens had long or intermediate pubescence on the upper sheaths, distributed as shown in Table 7.

TABLE 7.—Length of Average Middle Hairs of Uppermost Sheaths of 74 Individuals with Long or Intermediate Hairs (Mass Collection No. 3).

0.2 mm. — 2	1.1 mm. — 5	2.0 mm. — 0	2.9 mm. — 0
0.3 mm. — 4	1.2 mm. — 2	2.1 mm. — 0	3.0 mm. — 1
0.4 mm. — 3	1.3 mm. — 0	2.2 mm. — 0	3.1 mm. — 1
0.5 mm. — 5	1.4 mm. — 1	2.3 mm. — 0	3.2 mm. — 0
0.6 mm. — 6	1.5 mm. — 0	2.4 mm. — 0	3.3 mm. — 0
0.7 mm. — 9	1.6 mm. — 1	2.5 mm. — 0	3.4 mm. — 1
0.8 mm. — 9	1.7 mm. — 0	2.6 mm. — 0	3.5 mm. — 1
0.9 mm. — 8	1.8 mm. — 1	2.7 mm. — 0	3.6 mm. — 1
1.0 mm. — 12	1.9 mm. — 0	2.8 mm. — 0	3.7 mm. — 1

The six individuals with longest hairs had spikelets 1.8-2.0 mm. long, and the hairs dense and horizontally spreading. They were therefore determined as typical *P. praecocius*. Of the rest, 68 had uniformly long hairs on the upper sheaths, and 3 an assortment of irregularly long and medium hairs. All the latter three had spikelets 1.6 mm. long, somewhat longer than in accompanying plants of either *P. implicatum* or *P. meridionale*, between which they were othewise intermediate. Table 8 gives the spikelet lengths of 68 individuals with uniformly long hairs on the upper sheaths.

TABLE 8.—Length of Spikelets of 68 Individuals With Uniformly Long Sheath Hairs (Mass Collection No. 3).

1.2 mm. — 5	1.6 mm. — 1
1.3 mm. — 43	1.7 mm. — 1
1.4 mm. — 13	1.8 mm. — 1
1.5 mm. — 4	

The last three, with relatively large spikelets, also had rather long sheath hairs (1.4 mm., 1.6 mm., and 1.8 mm.; see Table 7), being thus intermediate in two characters between *P. implicatum* (as represented in this locality) and *P. praecocius*. The others, with shorter spikelets and shorter sheath hairs, are readily assignable to straight *P. implicatum* of the form represented in the other mass collections.

All the plants showed definite habitat preferences. *P. praecocius* was largely confined to the drier areas, where it grew with *P. Scribnerianum*. *P. meridionale* was found in low, rather damp areas, growing in mats of moss (two species of *Polytrichum*). *P. implicatum* grew with *P. meridionale* and extended part way into the territory occupied by *P. praecocius*. The intermediates between *P. implicatum* and *P. praecocius* were confined to the transitional zone in which both parents were found; intermediates between *P. implicatum* and *P. meridionale* were confined to lower areas, with the latter species. It should be noted that the lower ground and the transitional part of the territory occupied by *P. praecocius* are subject to flooding in spring, though usually fairly dry most of the summer and fall—again the sort of situation in which hybrids are to be expected with more than ordinary frequency.

MASS COLLECTION 4: Sandy roadside and ditch bank north of Princeton, Green Lake Co. *Panicum linearifolium* and *P. implicatum* present, only the latter included in the mass collection.

TABLE 9.—Length of Spikelets of 46 Individuals (Mass Collection No. 4).

1.2 mm. — 11	2.5 mm. — 6
1.3 mm. — 12	1.6 mm. — 2
1.4 mm. — 15	

TABLE 10.—Length of Middle Hairs of Uppermost Sheaths of 34 Individuals (Mass Collection No. 4).

0.5 mm. — 1	0.9 mm. — 2	1.3 mm. — 7
0.6 mm. — 0	1.0 mm. — 3	1.4 mm. — 4
0.7 mm. — 1	1.1 mm. — 5	1.5 mm. — 3
0.8 mm. — 1	1.2 mm. — 7	

Obviously a single species is represented, agreeing in essential characters with one of the two found in mass collection 1 (Tables 1 and 2).

It is clear from the above that recognizable species exist, separated by pronounced gaps in diagnostic characters; and that they remain uniform and distinct when growing alone, or growing together without disturbance, but that when growing together and subject to abnormal disturbance, some commingling of characters through hybridization may take place. Study of ordinary herbarium specimens confirms these conclusions, and indicates further that apparent hybrids are not extremely common.

Much supplementary information—for example, concerning the relative abundance of each species in a particular locality with relation to slight differences in habitat—might be obtained from further intensive population studies. The sole purpose of the present study has been to verify the existence of "empirically existing discontinuities." The above mass collections are inadequate for any elaborate statistical analysis or detailed comparisons with respect to particular species. No attempt is made to do more than record the evidence they give in support of the recognition of species.

The question of hybrids in Panicum deserves special comment. Church (1929), working with spring material only, found the plants he studied to be highly pollen sterile, a frequent characteristic of hybrids. This, in company with chromosomal irregularities, he took to indicate "a considerable degree of hybridization between the species." Hybridization may explain pollen sterility, but does not account for the concomitant peculiarities of a double flowering period and the fertility of the autumnal phase, characteristic of the whole subgenus *Dichanthelium*. The subgenus is defined by Hitchcock and Chase (1910) in part as follows: "In spring producing . . . terminal panicles with numerous spikelets, these rarely perfecting seed; . . . the secondary autumnal panicles reduced, . . . cleistogamous and perfecting their grains." As has been indicated, apparent hybrids are found in nature, but that many of the present-day species of Panicum are the products of hybridization, as assumed by Church, is very doubtful.[1]

1 Church unfortunately does not state how many plants he examined, where his material was collected, by whom it was identified, or whether herbarium specimens were preserved for later verification. His published findings are consequently of little value as far as their application to the taxonomy of the group by others is concerned.

With vernal flowers highly pollen sterile and the autumnal cleistogamous, the formation of hybrids would be very unlikely; yet there is good evidence that hybridization does take place. It is evident that the biology of these plants is in need of investigation.

Excluded Species and Varieties

Fernald, while acknowledging the great amount and usefulness of the work done by Hitchcock and Chase, has also (1934) called attention to the frequent disagreement between their descriptions and specimens named by them. Hitchcock and Chase of course examined an enormous number of specimens, and while the proportion of erroneous identifications may be small, the total is sufficiently large to vitiate seriously the value of the official Revision of Panicum label as a mark of reliable identification, at least in the groups containing *P. implicatum, P. tsugetorum,* and their relatives.

With shortcomings in keys and descriptions, it was to be expected that others should frequently find difficulty in following Hitchcock and Chase in recognizing species of Panicum. In an effort to provide a more satisfactory treatment, Fernald in 1934 published an extended preliminary commentary on eastern Panicums, discarding many superfluous species and reducing others to varieties. Some of his changes are satisfactory for Wisconsin plants, and have been followed here; others either await further study or are not acceptable for this region. After reading his paper, one feels that his pungent remarks, though often apt and to the point, have not been an adequate substitute for a full key or an extended discussion of the means of recognizing groups or separating closely related species.

It has been found necessary in the present revision to discard a number of names employed by other authors. The following species and varieties are reported for Wisconsin in Hitchcock's *Manual* (1935) or by Fernald (1934), but for the reasons given are not retained in this treatment:

1. *P. Boscii* Poir. A number of specimens with the short spikelets of *P. latifolium* and more or less pubescent or pilose nodes were labelled *P. Boscii* by Hitchcock and Chase. Since no Wisconsin specimens have spikelets 4 to 4.5 mm. long as required for *P. Boscii,* that species is excluded, collections so named being considered forms of *P. latifolium.*

2. *P. capillare* var. *occidentale* Rydb. Measurements of spikelet length for all available Wisconsin specimens of *P. capillare* show a continuous range from 1.9 to 3.3 mm., with the largest number falling between 2.5 and 2.8 mm. On this basis, the Wisconsin plants cannot be divided into two groups. Specimens from the Rocky Mountain and Pacific Coast states do have consistently larger spikelets and a somewhat different aspect, but spikelet length alone is not sufficient to separate them from plants of midwestern and eastern states. In Wisconsin, two forms of *P. capillare* can often be recognized: a neat, single-stemmed, erect little plant with a stiff panicle; and a large, coarse, several-stemmed, branched plant, with branches decumbent at the base, and an often lax panicle which may be only a third as long as the whole plant.

The differences are not only ecological, but genetic: both forms occur in a variety of habitats and can often be distinguished in seedling stages. But there is much intergradation, and these gross features do not correlate with spikelet measurements. Consequently *Panicum capillare* is here regarded as a single variable species without recognizable varieties in this region.

3. *P. huachucae* Ashe, Jour. Elisha Mitchell Soc. 15:51, 1898. The original description calls for a plant 2-3 ft. (about 65-95 cm.) high, with spikelets nearly 1" (2 mm.) long. The description in Hitchcock and Chase's monograph (p. 215) calls for a plant with culms 20 to 60 cm. high, and spikelets 1.6-1.8 mm. long. The latter authors selected as type a specimen in the National Herbarium whose label bore the same data as one of several cited by Ashe (who designated no type): a Lemmon specimen from the Huachuca Mountains, Arizona. In view of the discrepancy in their descriptions, it may be questioned whether Hitchcock and Chase were correct in designating their type, especially in the absence of proof that the specimen or an unquestionable duplicate of it was seen by Ashe. It is somewhat unusual for a plant of the Huachuca Mountains to be one of the commonest species in the northeastern United States. In any case, the name is antedated by *P. implicatum* Scribn., from which I am unable to separate *P. huachucae* of Hitchcock and Chase.

4. *P. huachucae* var. *fasciculatum* (Torr.) F. T. Hubb.; Hitchcock, Man. p. 634. I am unable to distinguish this from *P. implicatum.*

5. *P. lanuginosum* Ell. and varieties. (Fernald, 1934.) As has already been stated, Fernald's arrangement of varieties is unsatisfactory for Wisconsin. As for *P. lanuginosum* itself, the few Coastal Plain specimens of it which I have seen suggest that it is better considered apart from the northern *P. implicatum.* The long hairs of the primary leaf sheaths are much more dense, and tend to be matted or somewhat curled, which is never true of *P. implicatum.* The differences are not striking in the herbarium, but field experience with *P. implicatum* and *P. albemarlense,* for which a similar situation obtains, leads me to believe that it is unsafe to adopt the name *Panicum lanuginosum* for plants of Wisconsin.

6. *P. Lindheimeri* Nash, Bull. Torr. Bot. Club 24:196-197, 1897. Nash's description calls for a plant with ligule about 2 mm. long, and leaf blades 2-7 cm. long by 4-12 mm. wide. The description in Hitchcock and Chase's monograph (p. 203) calls for a plant with ligule 4-5 mm. long, and leaf blades 5-10 cm. long by 6-8 mm. wide. Such discrepancies again arouse suspicion, which is augmented by the fact that the latter authors extend the range from the original Texas and New Mexico to Maine, Minnesota, California, and Florida. *Panicum Lindheimeri* may well be a distinct species of the southwest, as it appeared in Nash's original discussion. The adoption of the name for plants of the northeast is at least fraught with uncertainty, and I prefer not to take it up at present for plants of Wisconsin. I am not able to distinguish *P. Lindheimeri* of Hitchcock and Chase from *P. implicatum* in this region.

7. *P. Lindheimeri* varieties. (Fernald, 1921.) As indicated under *P. lanuginosum,* I am not able to use Fernald's treatment of these in Wisconsin.

8. *P. pseudopubescens* Nash. Midwestern collections so named belong partly to *P. euchlamydeum*, partly to *P. praecocius*, and partly to *P. implicatum*.

9. *P. scoparioides* Ashe. Excluded for the same reason as no. 8.

10. *P. sphaerocarpon* Ell. A single specimen in the University of Wisconsin Herbarium so determined is *P. boreale*.

11. *P. subvillosum* Ashe, Jour. Elisha Mitchell Soc. 16:86-87, 1899. Ashe's description calls for a plant 15-30 cm. tall, with primary leaf blades 3-4 cm. long by 3-5 mm. wide, ligules 2 mm. long, panicle 2-3 cm. long, exserted on a peduncle 6-12 cm. long, and spikelets 1.5 mm. long. The description in Hitchcock and Chase's monograph (pp. 227-228) calls for a plant 10-30 cm. high, with primary leaf blades 4-6 cm. long by 4-6 mm. wide ("rarely wider"), ligules 3 mm. long, panicle 3-5 cm. long, and spikelets 1.8-1.9 mm. long. The latter authors add that the species "may be distinguished from *P. implicatum* and *P. meridionale* by the larger spikelets" as well as by other characters. The type specimen was collected at Carlton, Minnesota, "in the simple state," in August. Carlton is almost due west of Superior, Wisconsin, within 15 miles of the state line as the crow flies. There is no recognized species of Panicum in that area which fits Ashe's description. The extremely long-exserted small panicle characterizes members of the Depauperatum group, but the leaf proportions do not agree. The short spikelets (smaller than the minimum allowed by Hitchcock and Chase!) and absence of secondary fine pubescence suggest *P. albemarlense* or *P. implicatum*, for which the long exserted panicle is not characteristic. The late flowering is abnormal for all our species of the subgenus *Dichanthelium*. Without seeing Ashe's type, I cannot say what his plant probably was; it may have been a mixture. In any event, all the recognized species to which it might belong have more satisfactorily applicable and mostly earlier names. According to the critical characters emphasized by Hitchcock and Chase, the type specimen cannot be *P. subvillosum*. Most of the specimens so named by them are *P. implicatum*, in the inclusive sense of the present revision.

12. *P. tennesseense* Ashe. This appears to be a glabrate form of *P. implicatum*, not specifically separable from it.

13. *P. Tuckermani* Fernald. I am unable to distinguish this satisfactorily from *P. philadelphicum*. Steyermark and Schmoll (1939) have reduced it to a variety of that species, but since they devote five pages to showing that there are no reliable characters to separate the two, and the supposed difference in range is largely nonexistent, there seems little point in retaining it at all.

14. *P. villosissimum* Nash. Excluded for the same reason as no. 8.

15. *P. virgatum* var. *cubense* Griseb. Spikelet measurements for the species in Wisconsin show a continuous range from 2.8 to 5.5 mm. in length, the majority falling between 3.5 and 5 mm. Consequently I am considering the

four specimens seen which fall within the limits assigned to var. *cubense* (2.8-3.2 mm.) as simply small extremes of ordinary *P. virgatum*.

It only remains to add that, in addition to six seasons of field work, this revision has been based on a study of specimens in the herbaria of Michigan State College, the Milwaukee Public Museum, the University of Minnesota, the University of Wisconsin, and the private herbarium of S. C. Wadmond, Delavan, Wisconsin. In addition, through the kindness of Mrs. Chase, selected specimens of *Panicum albemarlense* and *P. meridionale* were loaned from the National Herbarium; the types, now temporarily stored outside Washington for safe-keeping, are not at present available for study. Grateful acknowledgment is made to the curators of the various herbaria for their courtesies, and to Mr. C. A. Weatherby for critical reading of the manuscript of this paper. Financial support for these studies was given by the Wisconsin Alumni Research Foundation.

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The Soil Series Represented in Hidalgo County, Texas[1]

F. L. Wynd

Introduction

The state of Texas comprises almost one eleventh of the area of the Continental United States. It has 167,754,880 acres of soils. About 35,000,000 acres, or 21 per cent, of this enormous area has been studied in detail by the cooperative activities of the Texas Agricultural Experiment Station and the Bureau of Chemistry and Soils of the United States Department of Agriculture. The magnitude of the task assumed by these organizations, and the great difficulty of travel in some areas can scarcely be appreciated by persons who have not had actual field experience in the study of soils. The criticism which the author has occasionally heard of erroneous boundaries ascribed to certain soil types seems a small criticism, indeed, in view of the quality and volume of publications proceeding from the activities of those engaged in studying the soils of Texas.

The soils of Texas range through every textural class. They are of many colors, and they vary widely in their agricultural value. The variations in parent materials, climate, and soil-forming agencies have produced a bewildering array of soils which have been classified into more than 130 Series and subdivided into more than 500 Types.

Climate of the Lower Rio Grande Valley

About two-fifths of Texas is included in the eastern humid area. The warm climate produces rapid weathering of the parent materials, but the rainfall is heavy enough to leach the products of weathering from the soil, hence there is no zone of lime accumulation, and the ratio of the oxides of iron and aluminum to silica shifts to a smaller value as metallic oxides are leached from the upper part of the profile.

The western three-fifths of the state lie in the subhumid or arid region. Here, the rainfall is not sufficient to leach the products of weathering from the profile, and as a result the soils are alkaline in reaction because of the accumulation of carbonates, have moderate to high concentrations of soluble salts, and have a layer of carbonate accumulation at some level in the profile. Figure 1 indicates the approximate boundary between the eastern pedalfer and the western pedocal soils.

The Lower Rio Grande Valley lies in the Gulf Climatic Province as described by Ward (13). The subtropical temperature and the limited rain-

1 The expenses incurred in this study were borne by the Cerophyll Laboratories, Inc., Kansas City, Missouri.

fall have caused the soils to develop into the pedocals typical of these climatic conditions. The temperature varies about 25° F. during the year. The lowest recorded variation is 24° at Brownsville and the highest is 30° at Rio Grande City. The absolute maximum officially reported is 110° F. at Mission on July 12, 1923, and the absolute minimum was 12° F. at Brownsville, on February 13, 1899. The absolute range therefore is 98° F. The dry cold "northers" usually do not cause freezes unless the wind dies. The wet "northers" usually are not of freezing temperature. August is the warmest month. Foscue (4) believes that this warm period may be due to the Gulf Stream which is at its highest annual temperature in August, according to the data of Brooks and Fitton (1). An additional cause is the prevailing winds from the south or southeast during this period. January is the coldest month. January is the last of the three months during which the prevailing winds come from the land, and this month probably exhibits the extreme influence of the cold, northern interior of the continent. During February, the temperature rises rapidly as the winds shift to the southeast. The effects of the subtropical temperature, indicated in Fig. 2, on the soils of the area are apparent in their low content of organic matter and in their rapid mobilization of new solutes useful to plants as they are withdrawn by heavy cropping.

Fig. 1. The physiographic divisions of Texas. The dotted line separates the western pedocal soils from the eastern pedalfer soils (Carter 1931).

The rainfall, unlike the temperature, varies significantly in the various parts of the Lower Rio Grande Valley. It ranges from 30 inches annually at Port Isabel to only 16 inches at Rio Grande City about 100 miles away, even

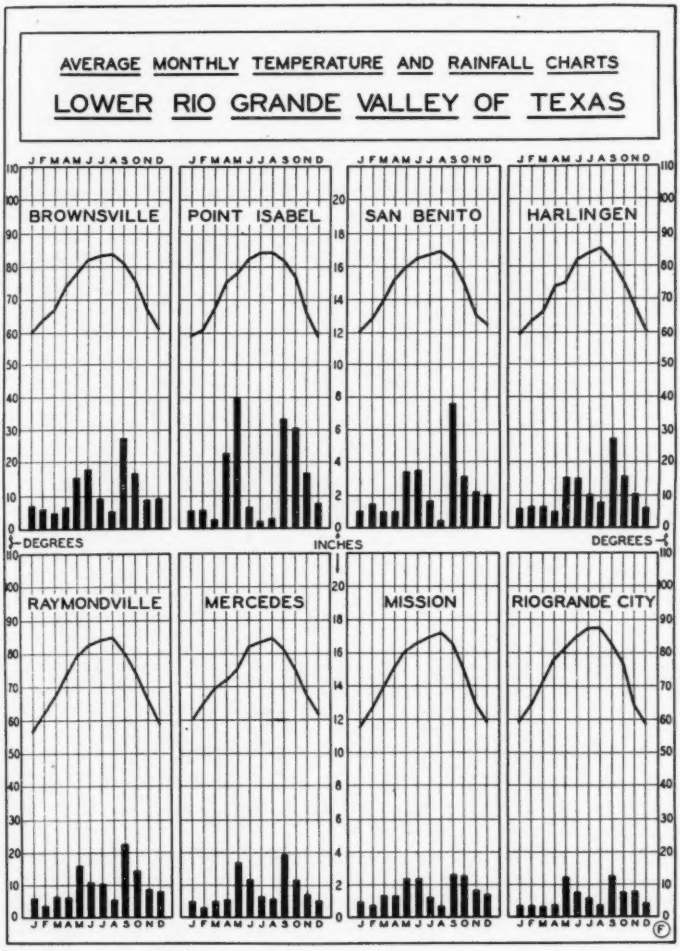

Fig. 2. The average monthly temperature and rainfall in the Lower Rio Grande Valley (Foscue 1932).

though the intervening territory is comparatively level. Foscue (4) has described the rapid decrease inland as dependent on three factors: 1. The southwestern section is beyond the normal course of the southerly, moisture-laden winds. 2. The southwestern part lies more in the horse-latitudes of higher pressure for a longer part of the year, and it is therefore less often influenced by tropical storms. 3. Fewer tropical disturbances affect the southwestern part, since it is out of the usual line of travel of these storms from their southeastern place of origin.

This rapid decrease in rainfall inland from the Gulf is represented in Fig. 3. This distribution of rainfall has important effects on the soils of the region. In Hidalgo County, for example, the darker soils and those containing less carbonate in the upper layers are generally those receiving the most rainfall.

The precipitation varies widely in different years. Records at Brownsville from 1893 to 1902 show a 10-year drought during which the annual precipitation was less than 10 inches. This was a period of great agricultural loss. Cattle died of thirst and crops failed. Another drought occurred between 1915 and 1918 although the development of irrigation greatly lessened the loss to farmers and stockmen. During the 60 years for which records were kept at Brownsville, the highest annual precipitation was 60.06 inches in 1917.

The data of Foscue (4) collected from 8 stations in the Lower Rio Grande Valley show two maximum precipitation periods during the year. Figure 2 shows the first maximum as occurring from April to June, and the second from September to October. Tannehill (10) attempts to explain these two maxima by the monsoon character of the prevailing southeasterly wind. The periods of its advance and retreat respectively are May-June and September-October, and these periods of major shifts in wind direction are accompanied by an increased precipitation. At Brownsville the prevailing wind is southwest from November to January, and during this period there is a lessened rainfall.

Snow is rare, but almost all weather stations in the area have reported a little, occasionally as much as one inch. Hail is so rare as to be of no significance. The single exception was the destructive storm at McAllen, April 29, 1930.

The rate of evaporation in the Lower Rio Grande Valley is high. The International Water Commission for the United States and Mexico (8) reported data obtained at Mercedes which showed a loss of 75 to 125 inches, or 6 to 10 feet of water per year by evaporation. This rate of evaporation is reflected in the soils of the region because of its effect on the average depth of water penetration, and also because of its effect on the accumulation of salts at the surface of cultivated land. Over long periods it augments the carbonate accumulation at some level in the profile. Some authors believe that a high rate of evaporation of upward-moving, bicarbonate-laden soil water leads to the formation of the hard, cement-like caliche layer which is common in this area.

The Soils of the Lower Rio Grande Valley

The warm, arid climate of the Lower Rio Grande Valley has caused the soils to develop into the Pedocals typical of these conditions. Because of the local variations in rainfall there are transitional types, especially towards the Gulf, where the precipitation is adequate to leach the carbonates from the upper layers of the profile in limited areas. The parent materials are the outcrops of the various geologic formations described by Trowbridge (11, 12) and Wynd (14). They are calcareous clays, marl, various limy materials as well as non-calcareous clays and sands, all in various stages of consolidation. Some of the calcareous components in the present soils therefore have been contributed directly by the present strata in some instances, rather than developed as a product of weathering during the formation of the present soil. These differences in the parent material explain why some soil types of the area differ so greatly from their immediate neighbors in their chemical properties although the soil forming agencies may have been very similar.

The typical mature soil profile in the Lower Rio Grande area exhibits a zone of salt accumulation at a depth of 24 to 50 inches. The amount of this accumulation and the depth at which it occurs vary between wide limits because of variations in chemical composition and stage of weathering of the underlying geologic formations, because of varying porosities of the underlying material, and especially because of local differences in rainfall.

The following brief classification of the soils of Hidalgo County has been summarized from the report by Carter (2). Eight series were recognized by this author.

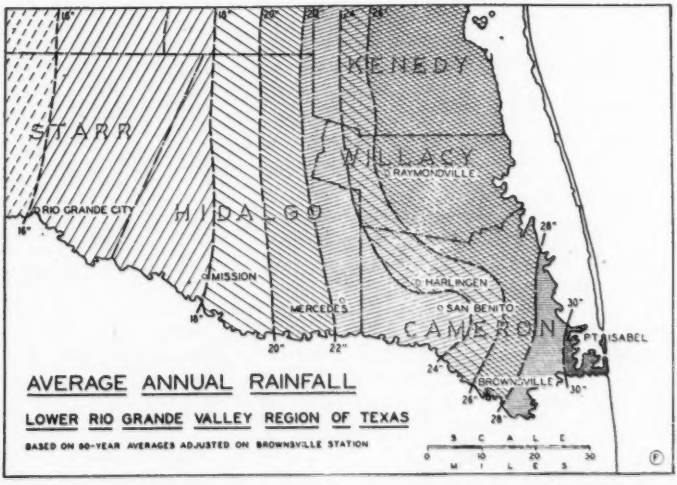

Fig. 3. The average annual rainfall in the Lower Rio Grande Valley (Foscue 1932).

Soil Series	Top soil	Subsoil	Substratum or parent material
I. Upland Plains			
A. Dark Colored Soils			
1. Victoria	Black to dark-brown, or dark-gray-brown, calcareous, friable	Dark gray, brown or yellowish, calcareous, crumbly	Calcareous clay or chalky marl
2. Hidalgo	Brown, calcareous, friable	Brown, or yellowish, calcareous, crumbly	Marl
3. Willacy	Brown, not calcareous, friable	Brown or yellowish, calcareous in lower part, crumbly	Marl
B. Light Colored Soils.			
4. Brennan	Very light grayish-brown, not calcareous, friable	Yellow, not calcareous, crumbly	Calich over sandy clay, in places slightly calcareous
C. Red Soils			
5. Duval	Red or reddish-brown, not calcareous, friable	Red, not calcareous except where thin, crumbly	Calich over sandy clays
II. Flat Stream-Bottoms			
6. Rio Grande	Brown, calcareous, friable	Gray to light-brown, or yellowish, calcareous, crumbly	Sandy clay and sand
7. Laredo	Light brown to gray, calcareous, friable	Brown or yellow, calcareous, crumbly	Sandy clay or gravel
8. Harlingen	Dark gray to dark brown, calcareous, heavy	Dark gray or brown, calcareous, dense	Clay

The paper by Fraps and Fudge (5) presents a more detailed and accurate description of the soils of the Rio Grande Plain. The following brief summary is condensed from this paper to include only the soils of Hidalgo County. Twelve Series were recognized.

I. Upland Plains Soils

A. Dark-colored soils

1. Hidalgo (Brown, calcareous, friable surface, with brown or yellowish calcareous, crumbly subsoil).
2. Tiocano (Dark ashy-gray clay surface extending to 3-4 feet without change, very tough when dry and plastic when wet).
3. Victoria (Black to very dark-brown, or dark-grayish-brown, calcareous friable surface with a dark gray, brown, or yellowish, calcareous, crumbly subsoil).
4. Willacy (Brown, noncalcareous, friable surface with brown to yellowish crumbly subsoil, calcareous in lower part).

B. Light-brown Soils

5. Delfina (Brown or reddish-brown, friable, non-calcareous surface with tough heavy gray or yellow, almost impervious, subsoil).

C. Light-colored soils

6. Brennan (Very light grayish-brown or gray, non-calcareous, friable surface, with a yellow, non-calcareous, crumbly subsoil).

7. Nueces (Gray, friable surface with a gray or yellowish, noncalcareous friable subsoil).

D. Red Soils

8. Duval (Red or reddish-brown, noncalcareous, friable surface with a red, crumbly subsoil noncalcareous except where thin).

II. Flat stream-bottom Soils

9. Harlingen (Dark gray to dark-brown, calcareous, heavy surface with a dark-gray or brown, calcareous, heavy subsoil).

10. Laredo (Brown, calcareous, friable surface with a brown or yellow calcareous, crumbly subsoil.

11. Raymondville (Gray to brownish-gray calcareous surface with light gray, ash-brown, or yellowish calcareous subsoil with poor natural drainage.

12. Rio Grande (Light brown, calcareous, friable surface with a gray to light-brown or yellowish calcareous crumbly subsoil).

The above summaries are of value to the trained student of soils but they are of little use to those who have but limited field experience in the region. For the benefit of the general student the following key to the soil series represented in Hidalgo County has been prepared on the basis of field characteristics. Ideally, it would enable the student to identify any soil series in the County. In most instances this is possible, but in others, only an experienced observer could correctly determine the Series under observation. However, the key does give a picture of how the various Series are related to each other and how they differ. A detailed description of each Series may be found in the report by Hawker, Beck and Devereux (6). The map accompanying this publication should be consulted for the detailed representation of the distribution of the soil Series and Types. The student should keep in mind constantly that a map necessarily must show areas as having definite boundaries, but it is indeed rare for the actual boundary of the area occupied by a soil Series or a soil Type to be even remotely a sharp line. The boundaries appearing on the excellent soil survey map of Hidalgo County prepared by Hawker, Beck and Devereux (6) must necessarily be more or less arbitrary. Where soil Series and Types grade gradually from one to another it becomes impossible to represent their areas on a map with accuracy.

A soil Series is regarded by pedologists as charactrized by a recognizable specific profile. This is much the same kind of concept that plant taxonomists have of the "type specimen" of a species, or of the "type species" of a genus. Since the materials being studied by both pedologists and taxonomists exhibit a wide range of variations, the actual delimitation in the one instance, just as in the other, is a personal and often subjective judgment which is only as good as the intelligence, training, and experience of the observer. It does not follow that the judgment of equally able and experienced students must be identical. The characteristic features indicated in the key which follows, the description of the characteristics, as well as the soil survey map mentioned above are intended as guides to the accumulation of field experience by students of the soils of the area, and are not intended as hard and fast definitions that could be applied by rule of thumb.

ARTIFICIAL KEY TO THE SOIL SERIES OF HIDALGO COUNTY

A. Soil occupying small, depressed areas rarely more than a few acres in extent, forming lagoons in wet seasons. Topsoil gray to black, tough. Subsoil not evident as a separate layer. ..... 1. *Tiocano*

AA. Soil not occupying small depressed areas. Topsoil not black, or if so, not tough.

B. Topsoil not calcareous.

C. Topsoil red or reddish-brown.

D. Subsoil at 12 to 20 inches, tough heavy clay-loam or clay. Topsoil more brownish than red. ..... 2. *Delfina*

DD. Subsoil at to 30 inches, compact sandy loam or clay-loam. Topsoil more reddish than brown. ..... 3. *Duval*

CC. Topsoil not red nor reddish-brown.

D. Profile largely of sand.

E. Topsoil containing at least a small amount of organic matter. Subsoil at 12 to 24 inches, lighter in color than the topsoil. ..... 4. *Nueces*

EE. Topsoil apparently devoid of organic matter. Subsoil not distinguishable as a separate layer. ..... 5. *Dune sand*

DD. Profile loamy or clayey.

E. Topsoil dark gray to black, normally not underlain by caliche. ..... 6. *Willacy*

EE. Topsoil brown, normally underlain by calich at various depths down to 18 feet. ..... 7. *Brennan*

BB. Topsoil calcareous.

C. Upland soils, typically coarse and sandy in texture. Not subject to overflow.

D. Topsoil dark-brown to black. ..... 8. *Victoria*

DD. Topsoil brown to light-brown. ..... 9. *Hidalgo*

CC. Lowland soils, subject to overflow by the Rio Grande, typically fine and clayey in texture.

D. Soils poorly drained.

E. Subsoil resembling topsoil, but slightly lighter in color. No limy specks, streaks, or concretions appearing at a depth of about 3 feet. ..... 10. *Harlingen*

EE. Subsoil more distinct from topsoil. Limy specks, streaks, or concretions appearing at about 3 feet. ..... 11. *Raymondville*

DD. Soils moderately to well drained.

E. Soils very low, frequently overflowed by the Rio Grande, continually ally being built up by alluvial deposits. Adjacent to the Rio Grande. ..... 12. *Rio Grande*

EE. Soils higher than the Rio Grande series, overflowed only rarely by the highest water, not being built up significantly by alluvial deposits. Near, but not adjacent to the Rio Grande. ..... 13. *Laredo*

1. *Tiocano.*—Tiocano clay is the only Type of this Series represented in Hidalgo County. It is dark gray to black in color. The material is homogeneous to a depth of 3 feet or more. It occupies depressed or porly drained areas within the Vivtoria, Hidalgo, Willacy, and Brennan Series. It is usually easily recognized by its black color and limited extent. Dirt roads across these low areas are very slippery when wet and assume a jet black color. The soil is sticky and plastic when wet and it is so stiff and tough when dry that it is almost impossible to bore into the subsoil with a soil auger. The areas form lagoons during wet seasons, some of which may persist for several years because of the extremely poor drainage.

2. *Delfina.*—The Delfina Series is represented in Hidalgo County by the

Fine Sandy Loam Type. The surface soil is light reddish-brown or red. It is not as red, however, as the Duval Series, and experienced observers can readily distinguish the Delfina from the Duval in the field. The surface color continues unchanged or becomes slightly lighter with depth. The surface soil is not calcareous. The subsoil appears at a depth of 12 to 20 inches and it is composed of tough heavy clay loam or clay which may be mottled with red, gray, or yellow. This tough clayey layer is hard when dry, and plastic and impervious when wet. This layer may continue without change to the caliche at a depth of 6 to 10 feet in which case it does not normally contain carbonate. More often, however, when the caliche is deeper than 6 feet, the clayey subsoil grades into a layer about one foot in thickness of light-brown clay loam at a depth of 3 to 4 feet which contains hard carbonate concretions in the upper part. There is reddish-brown calcareous clay loam below this, which continues downward to the caliche. This lighter-colored abrupt tough layer is the most important character which distinguishes the Delfina from the Duval Series. Northward of the area of typical Delfina there are considerable areas of the Nueces Series which show a definite reddish or brownish surface color. An examination of the thin layers of sand that accumulate in the bottom of the ripples which develop in abandoned fields shows these colors to be due to the moderately large sand grains. The Delfina grades northward into the Nueces by a more or less gradual loss of the surface color and by an increase in the depth at which the clay subsoil appears. It grades westward into the Duval Series by an increase in the red surface color and by the tough clayey subsoil giving way to a sandy subsoil.

3. *Duval.*—The Duval Series is represented in Hidalgo County by the Fine Sandy Loam Type and by a Deep and a Shallow Phase of the Fine Sandy Loam. The surface soil is red, or reddish brown and is not calcareous. At a depth of 10 to 18 inches this grades to a compact fine sandy clay loam or fine sandy clay which is somewhat plastic when wet, but this layer is never as tough and heavy as is the Delfina Series. The subsoil sometimes merges into a buff, yellowish, or reddish-yellow calcareous clay which contains carbonate concretions as a result of deposition from the surface leaching. At various depths, down to 6 feet, there is a hard caliche layer from 1 to 5 feet thick. The caliche becomes softer with depth and lies on sandy clay or compact sand which is sometimes interbedded with thin beds of sandstone. The Duval Series occupies the higher portions of the Hebbronville Plain described by Trowbridge (12).

4. *Nueces.*—The Nueces Series is represented in Hidalgo County by a Fine Sand Type which is separated into a Deep and a Shallow Phase. The surface soil is 12 to 24 inches deep and is composed of brownish-gray or grayish-brown fine sand. It is not calcareous and contains only traces of organic matter. The subsoil is a lighter grayish-brown, yellowish, or pale-yellow fine sand. It is not calcareous and may be several feet deep. At a depth of 3 to 6 feet the sand lies on a heavy clay which is gray or yellow, sometimes with reddish streaks. The upper part of this clay layer is not usually calcareous, although carbonate normally appears in the lower layers lying adjacent to the

caliche. The caliche layer is more extensively developed in the western examples of the Series.

5. *Dune Sand.*—The Dune Sand covers a comparatively large area. It is being constantly moved by the wind and therefore has not developed distinguishable layers in the profile. There is little or no organic matter, and the color is yellowish-gray or brownish-gray. It has been derived from the Nueces Series by the sorting action of wind.

6. *Willacy.*—The Willacy Series is represented in Hidalgo County by the Fine Sandy Loam Type. The surface soil is brownish-black to black. It is not normally calcareous. At a depth of 12 to 20 inches it grades into a light-brown, or yellowish-brown clay, fine sandy clay loam or clay loam which may be moderately heavy in texture. At a depth of 2 to 4 feet, the subsoil grades into a yellow-brown or cream-colored calcareous clay loam or clay which contains hard carbonate concretions. There is no well defined layer of carbonate accumulation. The Willacy Series grades westward into the Brennan rather abruptly by a loss of the black color and in the appearance of layers of carbonate accumulations. It grades southward gradually into the Victoria by the development of a calcareous topsoil and in the appearance of a layer of carbonate accumulation as a reason of surface leaching. Localized areas of poor drainage have developed many small areas of Tiocano clay which are exceptionally black in color and tough in texture.

7. *Brennan.*—The Brennan Series is represented in Hidalgo County by the Fine Sandy Loam, Light-colored Phase of the Fine Sandy Loam, Gravelly Loam, and Loamy Fine Sand Types. The topsoil is gray-grayish-brown, or brown, and it is not calcareous. It grades downward into a yellow or yellow-brown sandy clay or sandy subsoil. This, also, usually is not calcareous. At 2 to 3 feet, the subsoil grades into a buff calcareous clayey layer which is similar to that underlying the Hidalgo Series. Caliche occurs at a depth of 5 to 20 feet. Although both the topsoil and subsoil are described by Hawker, Beck and Devereux (6) as giving no field test for carbonate, many tests have shown that the subsoil frequently effervesces when treated with 5 per cent hydrochloric acid. There is a wide variation in the carbonate in the topsoil, and there are many islands within the Brennan area whose topsoils effervesce with acid. Chemical analyses, however, show considerably less carbonate in this material than in the typical Hidalgo Series which is its closest relative. Erosion prevents the development of the normal topsoil in many areas, and in these the soil usually contains more carbonate. In the more southern examples of the Brennan Series, erosion has exposed the hard caliche in many places.

8. *Victoria.*—The Victoria Series is represented in Hidalgo County by the Fine Sandy Loam, Fine Sandy Clay Loam, and Clay Loam Types. The surface soil is blackish-brown to nearly black in color. It is calcareous, and grades at 8 to 15 inches into a dark gray to brown, calcareous subsoil. At 3 to 6 feet, the subsoil grades into buff, yellow, or cream-colored soft calcareous clay or clay loam which contains soft lumps and streaks of carbonate. This layer is 1 to 2 feet thick and it is the layer of carbonate accumulation from

surface leaching. It merges into the light-colored chalky clay or marl of the parent material. The Victoria Series grades northward into the Willacy Series by a loss of the carbonate and the lessening or disappearance of the zone of carbonate accumulation. It grades eastward into the Hidalgo Series by losing the black color of the topsoil.

9. *Hidalgo.*—The Hidalgo Series is represented in Hidalgo County by the Fine Sand Loam, a Rolling Phase of the Fine Sandy Loam, Fine Sandy Clay Loam, Clay Loam, and by an Imperfectly Drained Phase of the Silty Clay Loam. The surface soil is light-brown to dark-brown and it is calcareous. The topsoil grades into a light-brown, grayish-brown calcareous clay or clay loam subsoil. The subsoil merges into a pale-yellow, cream-colored, yellowish-gray, or a pale-buff calcareous clay or clay loam which contains soft chalky calcium carbonate concretions. This is the zone of carbonate accumulation by surface leaching, and it merges into the parent material. Hidalgo soils merge eastward into the Victoria Series by the increase in organic matter and the consequent darker color of the topsoil. They merge northward into the Brennan by losing the calcareous nature of the topsoil.

10. *Harlingen.*—The Harlingen Series is represented in Hidalgo County by the Clay Type and by a Light-colored Phase of the Clay Type. It has an ash-gray to dark-gray, brownish-gray or grayish-brown, highly calcareous topsoil. At 12 to 15 inches it grades into a similar but somewhat lighter colored, calcareous subsoil. In some places the subsoil has layers of fine sand. This is the lowest and most imperfectly drained soil in the County, consequently it has a high concentration of soluble salts.

11. *Raymondville.*—The Raymondville Series is represented in Hidalgo County only by the Clay Type. The topsoil is gray, dark gray with a brownish cast, or brownish-gray, calcareous clay. At about 10 inches it grades into a lighter colored gray, light-gray, or ashy-gray, very compact calcareous clay. At 30 to 40 inches the subsoil grades into a grayish-buff or a pinkish-gray calcareous clay which may continue unchanged to a depth of 6 feet or more.

12. *Rio Grande.*—The Rio Grande Series is represented in Hidalgo County by the Very Fine Sandy Loam, Silty Clay Loam, and Clay Types. They have light-brown, or grayish, calcareous topsoils. The subsoil is similar but lighter in color. In places it has thin beds of sandy clay. The soils of the Rio Grande Series are continually being built up by the frequent floodings of the Rio Grande.

13. *Laredo.*—The Laredo Series is represented in Hidalgo County by the Silty Clay Loam and Clay Types. They have brown, calcareous topsoils which at 8 to 12 inches grade into a yellowish-brown or light-brown subsoil. There seems to be no layer of carbonate accumulation. The Laredo soils are subject to overflow only by the highest flood waters of the Rio Grande.

The areas occupied by the various soils of Hidalgo County tabulated from the data of Hawker, Beck, and Devereux (6) are as follows:

Series	Type	Acres
Victoria	Fine Sandy Loam	32,640
	Fine Sandy Clay Loam	11,392
	Clay Loam	35,840
	Total	79,872
Hidalgo	Fine Sandy Loam	105,280
	Fine Sandy Loam, Rolling Phase	1,472
	Fine Sandy Clay Loam	14,720
	Clay Loam	36,352
	Silty Clay Loam	1,856
	Total	159,680
Brennan	Fine Sandy Loam	306,624
	Fine Sandy Loam, Light Colored Phase	1,152
	Gravelly Loam	3,584
	Loamy Fine Sand	4,480
	Total	315,840
Duval	Fine Sandy Loam	75,904
	Fine Sandy Loam, Deep Phase	4,160
	Fine Sandy Loam, Shallow Phase	2,112
	Total	82,176
Nueces	Fine Sand	146,688
	Fine Sand, Shallow Phase	25,280
	Total	171,968
Delfina	Fine Sandy Loam	3,968
Willacy	Fine Sandy Loam	49,856
Tiocano	Clay	2,816
Laredo	Silty Clay Loam	11,968
	Clay	512
	Total	12,480
Harlingen	Clay	87,936
	Clay, Light Colored Phase	8,128
	Total	96,064
Rio Grande	Very Fine Sandy Loam	6,400
	Silty Clay Loam	14,272
	Clay	8,896
	Total	29,068
Raymondville	Clay	3,776
	Clay Loam	896
	Total	4,672
Dune Sand		960
	Grand Total	1,009,290

Agencies of Soil Formation in the Lower Rio Grande Valley

GENETICALLY RELATED GROUPS

The 12 Soil Series occurring in Hidalgo County may be arranged in groups of genetically related members. These relationships are determined primarily by the nature of the parent geologic formations, topography, agents of deposition, and rainfall. The groups are as follows:

I. Delta soils.
Rio Grand-Laredo-Harlingen-Raymondville.
These soils have been deposited by the Rio Grande. They are clayey in texture, and differ among themselves in drainage, and maturity of their profiles.

II. Upland soils.
Willacy-Victoria-Brennan-Hidalgo.
These soils have developed more or less from the underlying parent materials. They are mostly loamy in texture. They differ among themselves according to the

effects of rainfall on their vegetation, in the maturity of their profiles, and in the nature of the parent materials.

III. Sandy soils.
Duval-Delfina-Nueces-Dune Sand.
These soils are coarse-sandy in texture. They differ among themselves according to the amount and origin of their sandy components.

THE INFLUENCE OF GEOLOGIC FORMATIONS

A comparison of Figs. 4 and 5 indicates clearly the influence which the parent geologic formations have exerted on the development of the soils of the region. The Rio Grande, Laredo, Harlingen, and Raymondville Series coincide in extent very accurately with the Recent Fluviatile Deposits of the Rio Grande Delta. The Victoria, Willacy, Hidalgo, and the eastern extension of the Brennan, indicated in Fig. 5 by BrB, have been developed on the Pleistocene Beaumont Clay Formation. These soils vary in their carbonate and organic-matter content according to the rainfall and in texture according to admixtures of sand from the north. The western extension of the Brennan Series, indicated by BrA, is restricted to the Pleistocene Lissie Gravel and the

Fig. 4. The geological formations of Hidalgo County (redrawn from the United States Geological Survey data).

Pliocene Reynosa Sandstone Formations. The eastern and western extensions of the Brennan differ considerably because of the difference in rainfall and parent material. It is probably that these areas should be regarded as separate Series. The Duval, Delfina, Nueces, and Dune Sand are either coextensive with, or conspicuously influenced by, the area of Wind Blown Sand. Duval and Delfina Soils have developed on the non-calcareous northern outcrops of Pliocene Reynosa Sandstone. From the geologic map of Trowbridge (11, 12) it is evident that the Delfina and the eastern Duval Soils lie eastward of the mapped Reynosa Formation. The sandstone of the Reynosa Formation characteristically weathers to form red or reddish soils. It, therefore, appears reasonable to suppose that the geologic map, which admittedly is highly generalized, is in error and that all the red soils of this region represented in Hidalgo County by the Duval and Delfina Series have developed from the Reynosa Sandstone. It is probable, however, that there has been a copious admixture

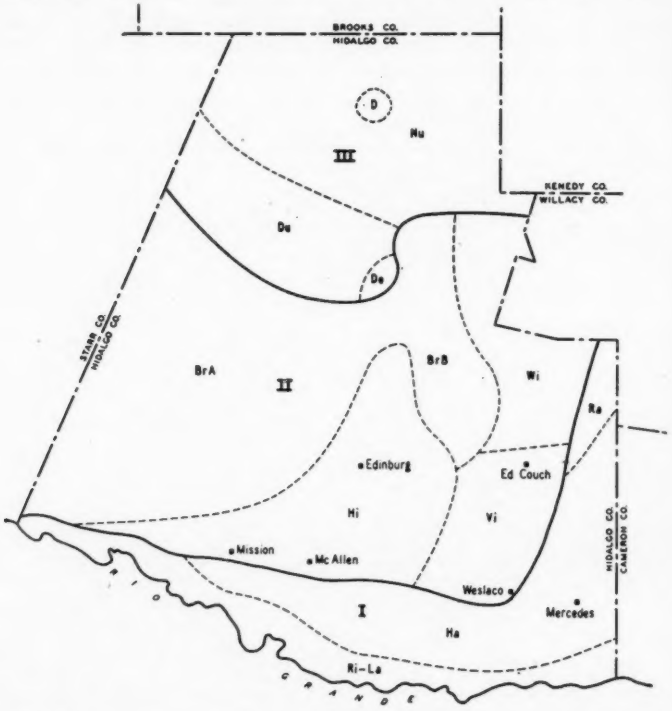

Fig. 5. Groups of related soils in Hidalgo County. I. Fluviatile soils, Rio Grande, (Ri); Laredo, (La); Harlingen, (Ha); Raymondville, (Ra). II. Upland soils, Victoria, (Vi); Willacy, (Wi); Brennan, (BrA BrB); Hidalgo, (Hi). III. Sandy soils, Duval, (Du; Delfina, (De); Nueces, (Nu); Dune Sand, (D).

of Wind Blown Sand brought about by the prevailing winds. This is especially true of the Delfina Series. The Delfina is browner than Duval because of this greater admixture of Wind Blown Sand. The Nueces representative of this group has developed from coastal sand transported inland by wind. The limited areas of Sand have developed by the sorting action of wind on the materials of the Nueces Series.

THE INFLUENCE OF AGENTS OF DEPOSITION

The prevailing winds and the waters of the Rio Grande are the agents of deposition which have been effective in modifying the present soils of Hidalgo County. The Rio Grande, Laredo, Harlingen, and Raymondville Series were deposited by the waters of the Rio Grande. These are all fine textured or heavily clayey. At the other extreme, in the northern part of the county, the Wind Blown Sand has been transported from the Gulf Coast entirely by the wind. As might be expected in an area whose topography is as level as that of Hidalgo County, the effect of this action of the wind is not narrowly localized. Consequently there has been a wide scattering of this sand southward. The topsoils of the upland soils between the Sand Dunes and the Rio Grande show a gradual lessening of the sand content, and in a progressive diminution in the particle size of the sand southward. Smith (9) has shown a somewhat analogous effect of wind-borne particles on the texture of Illinois soils. He reported that the differences in the texture of loess bears a linear relation to the logarithm of the distance from the original source. Also, the amount of loess transported is a linear function of the logarithm of the distance from the original source. Soils of the Rio Grande Delta show no significant admixture of sand from the north.

THE INFLUENCE OF TOPOGRAPHY

The topographic regions of the Lower Rio Grande as they appear in Fig. 6 divide the soils of Hidalgo County into three groups. The Nueces Series and the Dune Sand occur in the Sand Belts. The Dune Sand has been derived locally from the Nueces by wind action. The Duval, Delfina, Brennan, Hidalgo, Victoria, and Willacy Series occupy the Hebbronville Plain. They differ from each other according to the geologic formation from which they have been derived, the extent of admixture from the area of Wind-blown Sand, in the effects of rainfall on the development of organic material, and on the extent of leaching of the upper layers, and in differences in drainage due to topography and subsoil. The Rio Grande, Laredo, Harlingen, and Raymondville Series occupy the Rio Grande Delta, and are clayey in texture.

INFLUENCE OF RAINFALL

It has been pointed out in the section on climate that the rainfall decreases rapidly inland in the Lower Rio Grande Valley. A comparison of the belts of rainfall shown in Fig. 3 with the soil groups in Fig. 5 shows that these differences in precipitation exert important influences on the development of the various soil Series. This is particularly evidenced by the upland soils. The 20-

inch isopleth approximately separates the eastern black soils of the Willacy and Victoria Series which are comparatively rich in organic matter from the western brown or reddish soils represented by the Hidalgo and Brennan Series. Apparently an average annual precipitation of 20 inches or more was adequate to support the original grassland vegetation which led to the development of the dark colored soils of the Willacy and Victoria Series. This rainfall was also adequate to leach the calcareous material from the loamy top soils of the Willacy Series, a northern member of the black belt. It is probable that the poorer drainage of the heavier-textured Victoria of the southern extension of this belt has prevented the leaching of the calcareous substance from the upper portions of the profile. This difference in the amount of carbonate remaining in the upper layers of the profile is the main difference between the

Fig. 6. The physiographic divisions of the Lower Rio Grande region (Trowbridge 1932).

Willacy and Victoria Series. An exact boundary between these soils is difficult to determine, but many field observations have shown that the boundary established by Hawker, Beck and Devereux (6) is substantially correct.

The belt of precipitation between 18 and 20 inches includes the brown to dark-brown Hidalgo Series and the eastern extension of the Brennan. These soils have less organic matter than the black belt to the east, but they are distinctly richer in organic matter than the lighter colored soils of the western extension of the Brennan Series. The precipitation in this belt is sufficient to leach the calcareous materials from the upper layers of the Brennan at the northern extension of this belt. The poorer drainage of teh more clayey Hidalgo Series is probably the factor which has prevented a similar extent of leaching at the southern end of the belt.

The great area of Brennan Soils, indicated in Fig. 5 as BrA, lies in a belt whose annual precipitation is between 16 and 18 inches. This has permitted a very limited accumulation of the organic matter. Even though this area is well drained, the rainfall is not sufficient to leach an appreciable amount of the calcareous material from the upper layers of the soil profile. Many hundreds of field tests in this area have shown a sufficient amount of carbonate in the upper surface soil to effervesce with 5 per cent hydrochloric acid. Even where the topsoil did not effervesce, every sample collected below a depth of 8 inches showed a recognizable evaluation of carbon dioxide when treated with acid. This area of Brennan soil has a distinct gray or pinkish cast in contrast to the definite brown or gray-brown color of the eastern extension indicated in the figure as BrA. The typical Brennan Series, according to the definition of Hawkins, Beck, and Devereux (6) does not effervesce when treated with acid. This definition includes only that part which has developed on the Beaumont Clay Formation under a rainfall of 18 to 20 inches which is indicated as BrB in Fig. 5. The western component of this Series, which has developed on the Reynosa Sandstone and Lissie Gravel Formations, should probably be regarded as a separate Series.

The sandy Nueces, Delfina, Duval, and Dune Series composing group III in Fig. 5 have developed from non-calcareous sandy parent materials. In this area, the properties of the sand together with the fact that the materials have been more or less constantly disturbed during recent times, have prevented differences in precipitation from having any marked effect.

We may summarize the effects of the various soil-forming factors in producing the present complex of soil Series in Hidalgo County in the following outline. This outline, presented in a key form, attempts to arrange the soil Series according to their true genetic relationship. It would correspond to a "Natural Key" of the plant taxonomist. While it is of more value in understanding the soils of the region than is the "artificial" key presented above, it has but little value in the actual recognition of a soil Series in the field.

The Genetic Relationships of the Soils of Hidalgo County

I. Soils formed of transported materials.

A. Deposited by wind. Sand transported from the Gulf Coast.

1. Material more or less static. A youthful profile developing under a sparse vegetation. ..... 1. *Nueces*

2. Material constantly moving, profile undeveloped. ..... 2. *Dune Sand*

B. Deposited by Rio Grande. Erosional material transported from the far southwestern part of the United States.

1. Areas occupying the older flood plain and delta of the Rio Grande. Very poorly drained.

a. Profile more or less uniform, but lighter in color downward. Shows no carbonates accumulation due to leaching of the upper layers. ..... 3. *Harlingen*

b. Profile more developed. Limy streaks and concretions in the lower part of the profile due to leached material from the upper layers. ..... 4. *Raymondville*

2. Areas occupying the present erosional valley and flood plain of the Rio Grande. Moderately to well drained.

a. Areas low, and adjacent to the Rio Grande. Frequently flooded, and being continuously built up by flood deposits. ..... 5. *Rio Grande*

b. Areas higher, near but not adjacent to the Rio Grande. Rarely flooded and not significantly being built up at the present time. ..... 6. *Laredo*

II. Soils developed more or less *in situ* from the underlying parent material.

A. Developed from the Beaumont Clay Formation.

1. Rainfall adequate to allow the development of a black topsoil under an original grassland vegetation.

a. Drainage adequate to permit more or less complete leaching of the carbonates from the upper layers of the profile. ..... 7. *Willacy*

b. Drainage not adequate to permit leaching of the carbonates from the upper layers of the profile. ..... 8. *Victoria*

2. Rainfall less than adequate for development of black topsoil. The topsoil developed beneath the original sparse grassland vegetation is consequently brown.

a. Drainage adequate to permit the leaching of carbonates from the topsoil. ..... 9. *Brennan* (A)

b. Drainage not adequate to permit the leaching of carbonates from the topsoil. ..... 10. *Hidalgo*

B. Developed from the Lissie Gravel Formation.

1. Rainfall inadequate to permit the development of a black color. ..... 11. *Brennan* (B)

C. Developed from the Reynosa Formation.

1. Red weathered products of Reynosa Sandstone.

a. Profile consisting almost entirely of material weathered from sandstone, red. ..... 12. *Duval*

b. Profile exhibiting a brownish topsoil due to wind erosion of the red sand and from admixtures from the Wind Blown Sand from the Gulf Coast; clay layer in the subsoil which is probably related to the Beaumont Formation. ..... 13. *Delfina*

2. Grayish or vaguely-reddish weathered products of gravels, sandstone, and clay. ..... 14. *Brennan* (B)

Summary

1. There are 1,009,920 acres of soils in Hidalgo County, Texas, which are classified in 12 Series and 24 Types. These Series are genetically related by their parent geologic Formations, agents of deposition, topography, and rainfall.

2. The influences of each of these factors on the properties of the soils of Hidalgo County are discussed.

3. Previously published systems of classification of these soils are reviewed.

4. An artificial key to the soil Series of Hidalgo County, based on characteristics evident in the field, is presented as a means of identifying areas.

5. A natural key to the soil Series summarizes their genetic relationships.

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The Geologic and Physiographic Background of the Soils in the Lower Rio Grande Valley, Texas[1]

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Introduction

The author has been engaged during the past several years in a study of various environmental influences on the ability of grasses to synthesize vitamins and to accumulate protein in their leaves. Very early in the course of these investigations, it became apparent that there were many subtle, but often measurable, factors in the environment which profoundly influence chemical activities of plants. The relationships between activities of certain vitamins and deposition of protein are especially sensitive to environmental factors. The research program, therefore, was divided into two major sections. One line of study was the investigation of chemical relationships within the plant, with especial emphasis on the correlations of various components with the accumulations of vitamins and protein. At the same time an extensive program of field studies was begun to determine how the environment affected these various components which appeared to be correlated with vitamin activity and protein metabolism. In order to carry out this latter project, series of field plots were arranged on different soil types in three widely separated areas: Wallaceburg, Ontario; Midland, Kansas; and Elsa, Texas. Not only were experimental plots arranged in each area, but the effects of various soil types in each area were studied for their natural and undisturbed influence on the vitamin and protein metabolism of grasses. The investigations initiated at Elsa, Texas, has progressed further than those at Midland, Kansas, or at Wallaceburg, Ontario, and the results now appear sufficiently complete to warrant publication.

One of the most important results of this research was the unmistakable and systematic effect which the characters of the soil profile exerted on the vitamin and protein content of the grass leaves. Consequently, the study of the soil profiles became one of the most important phases of the problem. Through the generosity of the American Dairies Inc., and the Cerophyll Laboratories, Inc., of Kansas City, Missouri, the author has travelled more than 40,000 miles during his study of the soils in the Lower Rio Grande Valley. Many hundreds of profiles were studied in the field and approximately 20,000 chemical data were obtained in the laboratory.

The present paper presents a review of the physiographic and geologic history of the Lower Rio Grande region in an effort to explain how the present soils came to be developed in this area. Subsequent papers will report in detail

1 The expenses incurred in this study were borne by the Cerophyll Laboratories, Inc., Kansas City, Missouri.

the genetic relationships between these soils, their chemical properties, and the influence of selected soils on the vitamin and protein metabolism of grass leaves.

Geology

The present trend of many pedologists is to regard climate as the all-important factor in governing the course of development of soils from parent rock materials. This is true only in a special sense. If climatic effects be considered to be chiefly temperature and rainfall, then theoretically soils would ultimately assume a condition governed by the rate of rock weathering and by the rate of the removal of the products of weathering. These processes, however, produce characteristics observable over very wide areas and are usually of little value in the study of the differences in soil properties over a restricted area. The differences between soils of different but neighboring series usually must be accounted for on the basis of more specifically local factors than those of "climate."

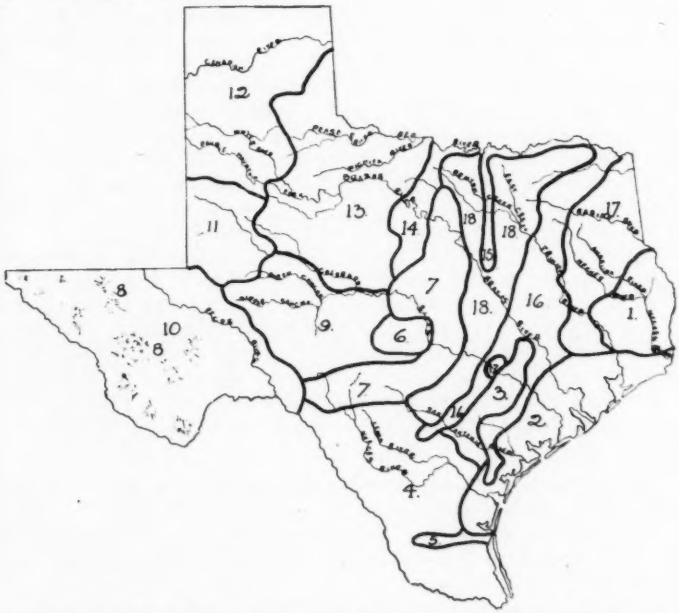


Fig. 1. The distribution of vegetation in Texas (Tharp 1939). 1, Long-leaf pine. 2, Coastal prairie. 3, Fayette prairie. 4, Mesquite—chaparral. 5, Coastal sand dunes. 6, Granite soil with oak and mesquite. 7, Edwards Plateau, oak—cedar. 8, Mountains: Guadalupe, Davis, Glass, Cathedral, Chenati, Chisos. 9, Live-oak, mesquite and Acacia on short grass. 10, Trans-Pecos: Sotol lechuguilla. 11, Sandy south plains. 12, High plains. 13, Mesquite—grassland. 14, Western cross timbers, oak—hickory. 15, Eastern cross timbers, oak—hickory. 16, Oak—hickory. 17, Loblolly pine, short-leaf pine and oak—hickory. 18, Black land prairie.

The characteristics of the soil profiles are very important physiographic features and they are intimately related to such properties of the parent strata as porosity, friability, degree of cohesion and consolidation, and stratification. It would be impossible to understand the relationships between Lower Rio Grande soils, as well as their individual characteristics, except in terms of their parent materials and the general physiographic characteristics of the region.

The importance of the approach to the study of the plant growth in an area by a preliminary examination of the geology and physiography of the region is apparent from a comparison of Tharp's (1939) vegetation map of Texas, reproduced as Fig. 1, with the physiographic maps appearing in the section describing the physiographic subdivision of Texas. The importance of geologic structures also is apparent from the work of Cuyler (2). This author published a detailed description of the correlation of the occurrence of certain plant species with the geologic formations in the area of the Austin Quadrangle. Many species of plants growing on soil derived from a given geologic formation were found to be as typical of that formation as the fossils that occurred within it. In general, he found an association of 2 or more dominant woody or non-woody species together with many subdominant species to typify geologic formations. The area studied was a Cretaceous section of the Travis Peak at the base of the Comanche Series through the Navarro to the Gulf Series of strata. In some instances, such as the Travis Peak and Glen Rose of the Comanche Series of the Trinity Division, the lithographic and geologic characters are poorly differentiated, yet these formations may be distinguished by the fact that the Travis Peak outcrop supports an association of *Quercus digitata* (= Spanish Oak) and *Sabina sabinoides* (Mountain Cedar) while the Glen Rose has only a few Spanish Oaks and an abundance of Mountain Cedar and *Schmaltzia lanceolata* (Sumac). In the western part of Texas, the outcrops of many igneous formations are clearly discernible from the vegetation cover. In northern central Texas, the Pennsylvanian-Cretaceous contact is marked by the presence of Post oaks and Black Jack oaks on the Cretaceous side. Aerial photographs have shown this correlation to be almost perfect. There are many instances, especially on the Coastal plain of Texas, where vegetation has revealed fault lines which the low and level topography otherwise would have concealed.

Clover (1) in her survey of the vegetation of the Lower Rio Grande described the close relationship that she found between the vegetation and the outcrops of strata of different geologic formations. The Zacatal or Prairie Grass region conforms in extent to the Recent wind blown sands and beach deposits. The Mesquital-Zacatal vegetation in Zapata County coincides with the Fayette Sandstone. The Mesquital is largely confined to the Reynosa Formation. Chaparral thrives along the Bordas Escarpment, and the plant, *Hechtia texensis*, prefers soils from the Cockfield Formation.

Many instances could be cited of the relation of geologic strata to plant growth, but a comparison of Figs. 2 and 3, reproduced from the publication of Clover will convince the reader that the agricultural characteristic of an area may be more closely dependent on the geologic structures than is sometimes

realized. We therefore preface our discussion of the soils themselves with a statement of the geologic history of the region. There is a vast technical literature treating of the geology of Texas, a complete review of which would be

TABLE 1.—The Sedimentary Strata of Texas.

Cenozoic	Quaternary	Recent Pleistocene
	Tertiary	Pliocene Miocene Oligocene(?) Eocene
Mesozoic	Cretaceous	Upper Cretaceous Comanchean
	Jurassic	
	Triassic	
Paleozoic	Anthracolitic	Permian Pennsylvanian Mississippian(?)
	Devonian(?) Silurian Ordovician Cambrian	
Archaezoic	Precambrian	

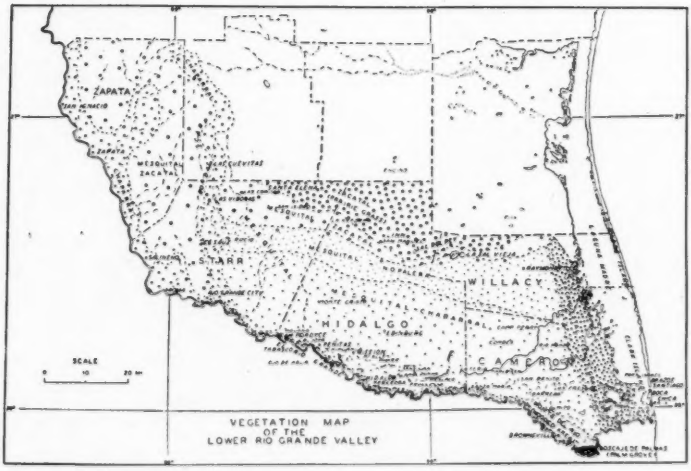


Fig. 2. Vegetation map of the Lower Rio Grande Valley (Clover 1937).

far afield from the present study. The briefest statement, consistent with the presentation of the essential facts is all that will be attempted in the present paper.

The sedimentary strata of Texas have been summarized by Udden, Baker, and Böse (15) in Table 1. The older rocks outcrop in Texas only in the interior. Figure 4, reproduced from the work of Hill (6), shows that the Central Denuded area exposes outcrops of Paleozoic and early Mesozoic. These strata dip unconformably below the younger deposits of the Llano Estacado and incline coastward beneath the intricate series of strata making up the coastal incline.

These old pre-Cretaceous rocks lie in a series of anticlines and synclines, which are the remains of an ancient topography eroded to base level during the Jurassic or very early Cretaceous. Later, but still during early Cretaceous, the sea advanced over Texas from the south and southwest, reworking the old soils and some of the underlying materials into new beach deposits as it advanced northward towards the Arctic Sea. Finally this invading sea covered all the land from the present Rocky Mountains eastward to the western Iowa and Minnesota, and northward to the Arctic regions.

In the later part of the Cretaceous, this sea slowly receded, leaving its sediments high and dry, until the entire region was again exposed land at the close of the Cretaceous.

Towards the close of the Cretaceous, this vast expanse of dry land was subjected to folding and tilting. The Rocky Mountains appeared as folds. The Trans-Pecos region of Texas also was folded into mountains during this

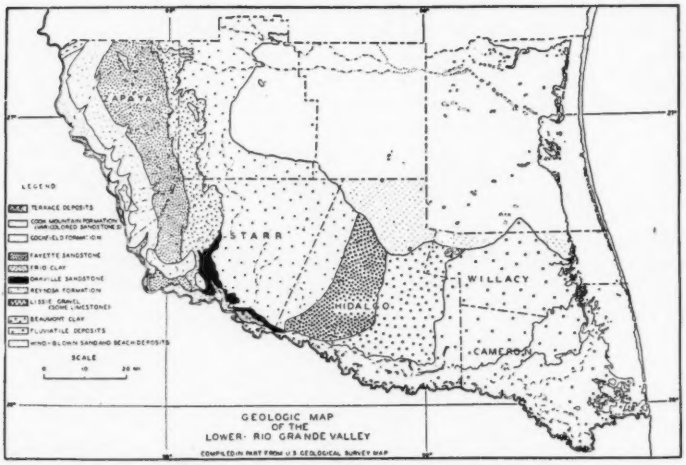


Fig. 3. Geologic map of the Lower Rio Grande Valley (Clover 1937).

time, and the general Texas area was tilted to form a gentle incline to the sea. Although these orogenic movements began in Late Cretaceous, they reached their culmination after the close of the Mesozois. Strains were produced in the great strata of chalky limestone known as the Comanche Series, and later, when this eroded and weakened foramtion was loaded with the later sediments of the Tertiary and Quaternary, the Balcones fault was produced. Although this fault probably began in Late Cretaceous, it was accentuated during Pliocene and Pleistocene by the weight of the sediments being deposited. This fault is revealed at the present time by the Balcones Escarpment, which is the outstanding physiographic feature of south central Texas.

By the end of the Cretaceous, the entire area had been markedly eroded, hence later Tertiary strata lie unconformably on it. Thse later strata include those of the Llano Estacado, and of the basins and plains of Trans-Pecos as well as those of the present Coastal incline.

Hill (5) describes exposures of the Cretaceous now known as the Eagle Pass Formation along the Rio Grande from the west of Eagle Pass to the Webb County line. They occur also as far south as the Santa Rosa Mountains in Coahuila, Mexico. These sediments lie unconformably on the Paleozoic and underlie the rich Black Prairie, westward of the Central Denuded area. Its soft, limy character, and the warm relatively humid climate, have produced some of the finest agricultural lands in Texas. Coastward, the Cretaceous dips gradually but deeply below the gently sloping plains which collectively make up the coastal incline. The line of contact between the outcrops of Cretaceous and Tertiary has been mapped in detail by Stephenson (11) and is shown in Fig. 5.

A very long period elapsed between the upper Cretaceous and the Eocene. This is shown not only by the great unconformity between these strata, but especially by the change in the fossils. No single species survived this long, unrecorded period, and there are only a few examples of the same genera being found in the Cretaceous and Eocene.

The soils that will be described later have developed from the sediments deposited by various agencies during the Cenozoic Era on the underlying Cretaceous strata. The formations of the Cenozoic Era which outcrop in the Rio Grande Plain are summarized by Udden, Baker, and Böse (15) in Table 2, and the Cenozoic strata that outcrop in the Lower Rio Grande Valley are summarized by Trowbridge (14) in Table 3.

Trowbridge (13) reports the average dip of the various Formations of the Rio Grande Plain as follows:

Formation	Dip in feet per mile
Beaumont	25
Reynosa	17
Frio	263
Fayette	201
Yegua	296
Cook Mountain	435
Mount Selman	180
Wilcox group	384
Midway	155

The average dip of the Eocene Formation is given as 273 feet per mile, although this value is probably too high since only the steeper dips are usually read. Probably a value of 100 or less would be more generally true. Schuchert (10) states that the average dip of the entire Mesozoic and Cenozoic strata is from 10 to 70 feet per mile towards the southeast and south. The average dip was found to be about 50 feet per mile. The older formations exhibit the greater dip. In the area of the Lower Rio Grande Valley, the younger strata are tilted to a very much less extent.

Foscoe (4) states that the difference in the elevation of Rio Grande City and Port Isabel is 153 feet. The average slope of the land surface therefore is only about 1.5 feet per mile in the Lower Rio Grande Valley. Since the Tertiary sediments forming the Coastal Plain have a greater dip coastward than does the surface topography, there is a succession of outcrops, generally in northeast-southwest bands, of successively younger rocks towards the Gulf Coast. The area between the Brazos and Colorado Rivers roughly marks the division between the northeastern and southwestern earlier Tertiary sediments. Eastward th deposits were laid down in the Mississippi Embayment and west-

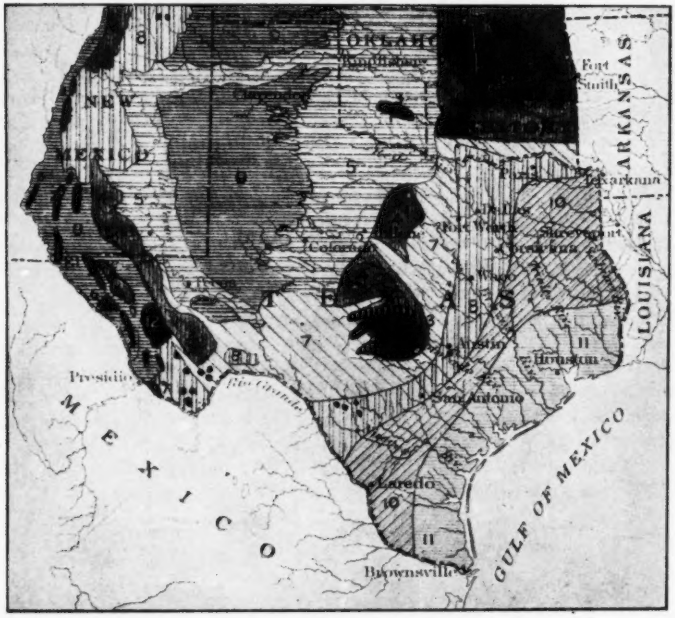


Fig. 4. Geologic map of the Texas Region (Hill 1899). 1, Older granite. 2, Paleozoic and Mesozoic. 3, Cambrian-Silurian. 4, Carboniferous. 5, Permian. 6, Jurassic. 7, Lower Cretaceous. 8, Upper Cretaceous. 9, Nonmarine Tertiary. 10, Marine Eocene. 11, Coast neocene. 12, Later igneous.

ward they were deposited in the Rio Grande Embayment, although after the close of the Oligocene, these two embayments were not clearly differentiated.

Throughout the Cenozoic Era the main trend has been deposition, although in Recent times, the gulf has retreated which causes the present shore line to be low and even. The succession of marine and terrestrial deposits records the history of the shifting coastline of the Gulf of Mexico. Many times the sea encroached far inland leaving sheets of marine deposits as evidence of its advance. During the intermittent periods of emergence, the large and heavily loaded rivers deposited sheets of terrestrial sdiments in the valleys and seaward along the coast. The terrestrial and marine sediments grade into each other in an intricate series of strata. Figure 6 illustrates graphically the relative extent and duration of these advances of the sea. The two types alternate with each other vertically and also laterally. The change may be abrupt or gradual.

Upper Cretaceous
Eocene Midway
Balcones Fault
Houston
Austin
Eocene
Miocene
Pliocene
Recent
Lower Cretaceous
Eocene Wilcox
Eocene Claiborne
Eocene Jackson
Eocene Vicksburg
Eocene Frio
Eocene Yegua
Eocene Fayette
Eocene Lissie
Eocene Manning
Eocene Weches
Eocene Queen City
Eocene Reklaw
Eocene Carrizo
Eocene Sparta
Eocene Cook Mountain
Eocene Mt. Selman
Eocene Crockett
Eocene Cane River
Eocene Sabine
Eocene Mt. Selman
Eocene Mt. Selman
Eocene Mt. Selman

TABLE 2.—The Sedimentary Strata which Outcrop in the Rio Grande Plain. (From Udden, Baker, and Böse, 1916)

Cenozoic	Quarternary	Recent	In the Eastern Gulf Coastal Plain	In the Western Gulf Coastal Plain
		Pleistocene	Recent Port Hudson-Columbia (Beaumont or Coast Clays)	Recent Port Hudson-Columbia (Equus beds)
	Tertiary	Pliocene	Lafayette, Lissie Fleming (in part)	Uvalde, Reynosa Lagarto Laparta
		Miocene	Fleming (in part)	Oakville
		Oligocene(?)	Corrigan (Catahoula or Grand Gulf)	
		Eocene	Jackson	
			Claiborne Yegua or Cockfield Cook Mountain Mount Selman Queen City Wilcox Midway	Claiborne Fayette 1 Frio Cook Mountain Mount Selman Carrizo 2 Wilcox Midway

1 Some geologists consider Fayette and Frio to belong to Jackson.
2 Some geologists consider Carrizo to belong to Wilcox.

The classification and correlation of the rocks of the Gulf Plain are made more difficult by their lithographic similarities. However, the rocks of the Lower Rio Grande have been fairly well classified and correlated on the basis of fossils, laboratory analysis, and stratigraphic breaks.

The following brief description of the strata outcropping in the Lower Rio Grande is condensed from the works of many authors. The reader should consult the publications of Trowbridge (13 and 14) for the complete description of the strata and for the exact location of their outcrops. A detailed discussion of these Cenozoic systems in Texas has been published by Plummer (9), and a summary of their most important characteristics appears in the monumental work of Schuchert (10). The extensive bibliographies published in these larger works will guide the student who wishes to pursue further the study of the geology of the Lower Rio Grande Valley. Unless otherwise noted the figures in the present paper representing the exposures of the various Formations have been redrawn and simplified from the data of Trowbridge.

EOCENE SERIES

Midway Formation.—The Midway is the thinnest formation occurring in the Lower Rio Grande Valley. This, together with the fact that it is overlapped by the Indio and Reynosa Formations, causes it to outcrop in only a few places in Maverick, Zavalla, and Uvalde Counties as shown in Fig. 7. Although there are only a few outcrops in our region, it has many important outcrops on the Mexican side of the river in the states of Coahuila and Nuevo Leon. It appears as a continuous belt from eastern Uvalde County to southwestern Arkansas. Most of the Midway rocks are shale, although there are layers and lenses of sandstone and limestone. The limestone is gray, compact, and in places, crystallized. The shale is dark or colored green, brown, gray, or blue, and it is frequently mixed with sand, silt and gypsum. The average thickness is 216 feet. Midway strata were deposited by the sea in its first advance inland over the old and much eroded Cretaceous strata. At the end of Midway time, the sea retreated and a long period of erosion followed.

Indio Formation.—The greater part of the exposed Indio Formation within our area lies on the Indio Ranch in Maverick and Dimmit Counties. It forms a belt 8 to 11 miles wide in western Dimmit, southeastern Maverick and northwestern Webb Counties as shown in Fig. 7. In Webb County, it is exposed for almost its entire thickness. It is chiefly composed of thin beds of laminated, argillaceous sand and sandy shale. There are some beds of heavy

TABLE 3.—The Outcrops of the Cenozoic Strata along the Lower Rio Grande. (From Trowbridge, 1932)

		Series	Group	Formation
Cenozoic	Quaternary	Recent		Coastal deposits Wind blown sand Fluviatile deposits
	System	Pleistocene		Beaumont clay Lissie gravel Terrace deposits
	Tertiary	Pliocene (?)		Reynosa Lagarto
		Miocene		Oakville sandstone
		Oligocene (?)	Vicksburg (?)	Frio clay
		Eocene	Jackson	Fayette sandstone
			Claiborne	Cockfield Cook Mountain Mount Selman
			Wilcox	Bigford Carrizo Indio
				Midway

clay, and layers and lenses of sandstone. The clay and shale are greenish, bluish-gray or brown, and usually contain gypsum. The sandstones are gray, yellow, green, or brown, and are of various textures. There are a few beds of lignite. The thickness of the Indio Formation at various places varies between 600 and 900 feet. These strata were deposited partly by marine and partly by land agencies on the eroded Midway. The character of the rocks and of the

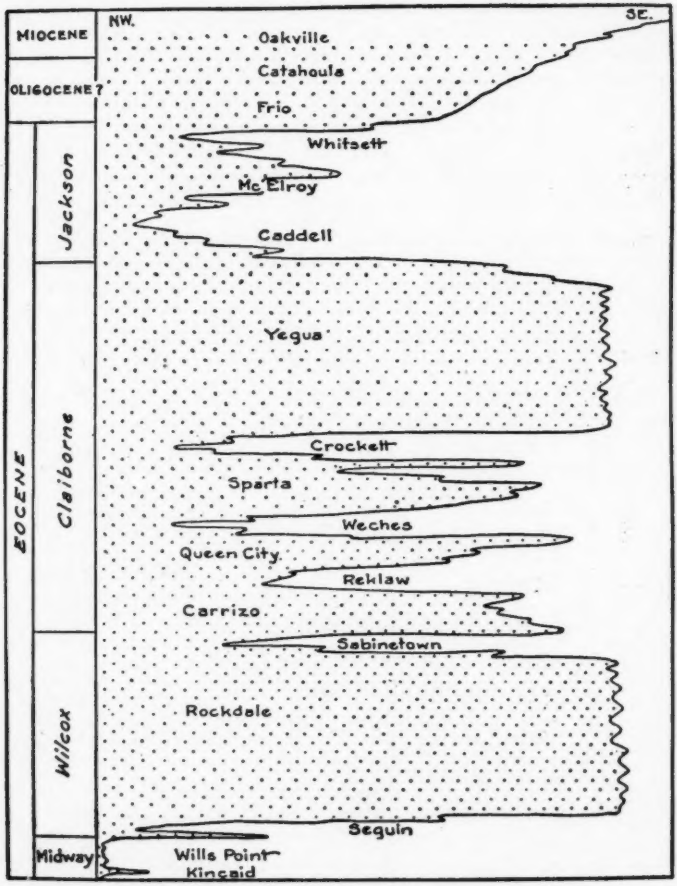


Fig. 6. Diagram to show the oscillations of the Gulf of Mexico across the Coastal Plain of East Texas during the Cenozoic. White, marine advances toward the northwest; dotted areas, retreat of the seas, with the deposition of non-marine formations. After Plummer (1933).

fossils which they contain indicate the presence of lagoons. It is probable that most of the deposition occurred on both sides of an oscillating shore line. The large amounts of quartz and feldspar and smaller amounts of zircon came from the mountains of Colorado, New Mexico, and northern Mexico.

Carrizo.—The Carrizo Sandstone outcrop is a belt about 3.5 miles wide in Webb and southern Dimmit, Zavalla, Maverick, and Uvalde Counties as shown in Fig. 8. In one place in Dimmit County, this belt is 7 miles wide.

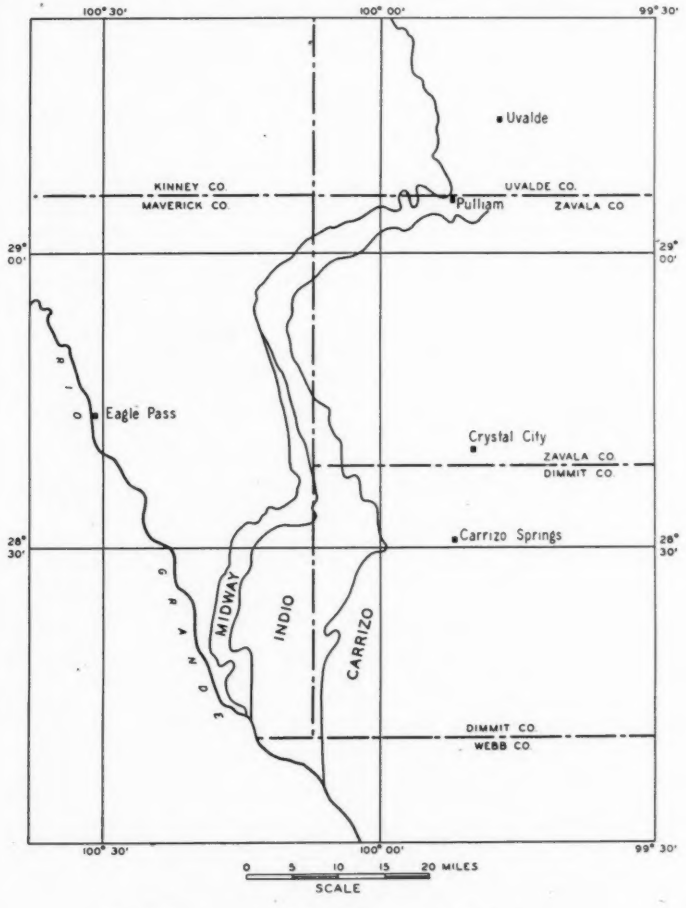


Fig. 7. The outcrops of the Midway and Indio Formations.

The Carrizo beds are more sandy than the other Wilcox Formations, and the sand is more firmly solidified. In places it is modified to quartzite. It is often very ferruginous, although some deposits are gray or white. There are a few beds of clay, shale, and limestone. Near Carrizo Springs, this formation is 200

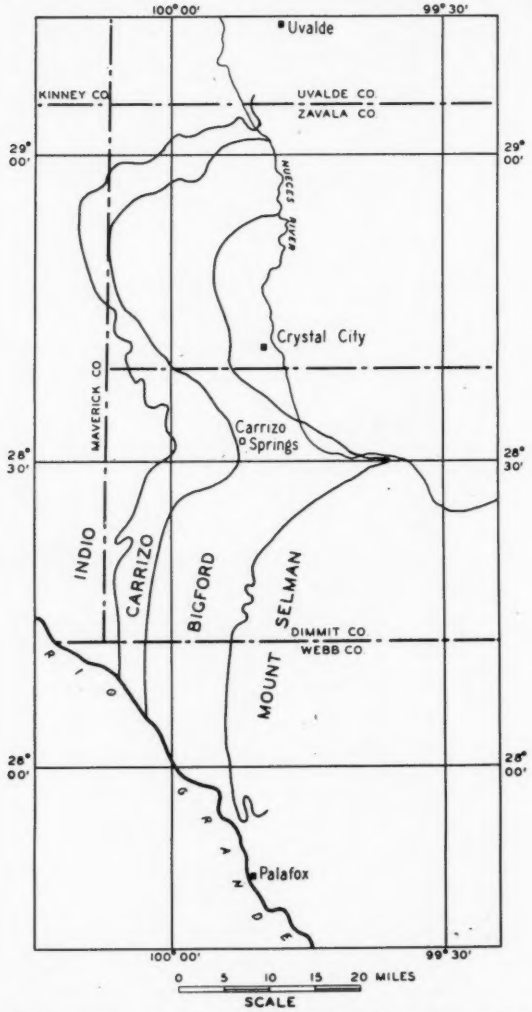


Fig. 8. The outcrops of the Carrizo, Bigford, and Mount Selman Formations.

feet thick, while it is only 118 feet thick where the Rio Grande cuts through it in Webb County. The Carrizo Sandstone lies unconformably on the Indio, although the character of the sediments is very similar to those of the Indio. Probably there was but a temporary interruption in the conditions of Indio deposition before the Carrizo was initiated. Like the Indio, much of the sediment was derived from the Cordilleran Mountains almost 500 miles away. The nearer exposures of Cretaceous sandstone also made a significant contribution. The nature of the sand grains indicates that wind was an important agency in transporting sand from the inland regions. These deposits of terrestrial origin were deposited in shallow lagoons and in the landward flats near the sea.

Bigford.—The Bigford Formation outcrop is about 10 miles wide in Webb County and about 8 miles wide near Carrizo Springs. Figure 8 shows the outcrop to form a north-south belt through the counties of Webb, Dimmit, and Zavalla. These strata consist mostly of clays of many different colors although there is a small quantity of gray, green, or brown sandstone, and a considerable number of lignite beds. There are many beds, lenses, and poorly bounded accumulations of yellow limestone, and some thin beds of hematite. The Bigford lies conformably on the Carrizo in a few places. Within our area it is 340 to 700 feet thick. These deposits are of land origin although they were probably laid down on a plain of deposition very nearly at sea level, and the conditions of deposition were probably determined by the nearby shore. The agent of transportation of the sediments to their present location was water rather than wind. Extensive bodies of shallow water permitted the formation of beds of lignite. The mountains of Trans-Pecos and the high plateau northwest of the present Balcones Escarpment contributed most of the material.

Mount Selman.—The Mount Selman Formation is not clearly separable stratigraphically. There is, however, a sufficient difference in the fossil flora to indicate some non-conformity. Figure 9 shows that the Mount Selman beds outcrop in a band about 16 miles wide in Webb and Dimmit Counties. It is 600 to 700 feet thick in our area. Clay, colored gray, black, greenish, or bluish when newly exposed or yellowish or buff when weathered, composes most of the Mount Selman strata. Some of the beds are sandy or limy. There are large deposits of gypsum in lenses, beds, joint fillings and in irregular crystalline aggregates. There are some beds of sandstone which may sometimes be 25 to 30 feet thick over short distances. They are only moderately consolidated and never form quartzite. There is a little limestone, and lignitic and bituminous coal is common. Calcareous concretions occur throughout the Mount Selman Formation. These concretions vary in size from that of a pea to 6 feet in diameter, averaging about 1 foot in diameter. The exposed area is characterized by a gently rolling topography with clay-loam soils. The origin of the Mount Selman Formation is obscure. The theory of its marine origin is based on the presence of limestone containing fragments of mollusc shells, the presence of a few Foraminifera, and conformity with the overlying marine Cook Mountain Formation. None of these evidences is conclusive. The coal and fossil plants are not typically marine in character. The conditions of sedi-

mentation were probably about the same as during the Indio and Bigford depositions.

Cook Mountain.—The Cook Mountain Formation is exposed in a belt

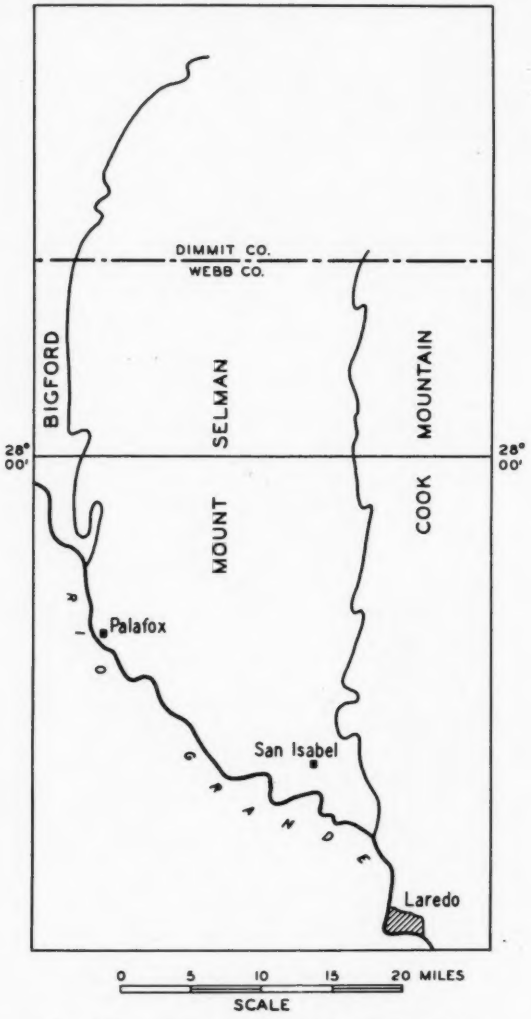


Fig. 9. The outcrop of the Mount Selman Formation.

about 13 miles wide in Webb and Zapata Counties as seen in Fig. 10. The base of this strata is cut by the Rio Grande 8 miles above Laredo. From here, the drop of the river very nearly parallels for 70 miles the strata of the Cook Mountain rocks and the river does not cut the top of the formation except at the Zapata-Starr County boundary, about 15 miles upstream from Roma. The Breaks of the Rio Grande expose this formation for a distance of 75 miles. The rocks of these strata are chiefly sand and sandstone, more or less finely cemented and are colored green, brown, red, yellow, or gray and is often glauconitic, ferruginous, or micaceous. There are a few cross beds of clay, and some thin lenses of limestone. The lower two-thirds weathers to form a red soil, while the upper third weathers gray. The soils developed from Cook Mountain strata are unusually rich. The thickness is from 700 to 900 feet. Fossils are numerous and highly characteristic and indicate an almost exclusive marine origin. The deposition occurred under rather uniform conditions over wide areas, probably in the open sea.

Cockfield.—The outcrop of the Cockfield Formation is from 4½ to 17 miles wide as shown in Fig. 11. It occurs in Webb, Zapata, and Starr Counties. Most of the material in these strata is carbonaceous clay, colored gray, black, red, pink, purple, green, or brown. There are a few deposits of sandstone which average 493 feet in thickness in the areas of their outcrop. Eastward, the thickness increases to more than 1500 feet as shown by oil and gas well borings. Deposition was in salt or brackish water, although possibly some occurred in fresh coastal water and bays. The sediments were derived from low lands to the west.

Fayette.—The Fayette Sandstone outcrops in a belt from 5 to 11 miles wide in Starr, Zapata, and Webb Counties as shown in Fig. 12. The rocks are lithologically similar to those of Cook Mountain and Oakville, but the fossils differ from those in these latter formations. The upper and lower boundaries are arbitrarily limited since they grade into adjacent formations. Fayette contains more sand and sandstone than other types of rock. The sandstones are white, gray, greenish, or buff. Texture ranges from fine to coarse; the degree of consolidation ranges from loose sand to quartzite. It is rich in fossils. There are also beds of shale and clay, but limestone is rare. There are a few beds of volcanic ash. Silicified wood is common in the clay and sandstone and its presence is characteristic of this formation. The thickness varies from 210 to 1000 feet with an average of about 530 feet, although gas and oil well borings have shown thickness up to 1600 feet in Webb and Zapata Counties. These strata were deposited mostly in marine or brackish water, but some were laid down in sandy or clayey coastal plains. The water was generally shallow, and the admixture of volcanic dust probably came from volcanoes outside of the region.

OLIGOCENE (?) SERIES

Frio.—The Frio Clay Formation is composed mostly of nonvolcanic clay. It outcrops in a belt of variable width along the west side of the Bordas Escarpment in southeastern Webb, eastern Zapata, western Jim Hogg, and

west central Starr Counties as is seen from Fig. 13. The clay beds are green, gray, yellow, or pink, and are unusually pure. There is a little admixture of fine quartz, and gypsum is sometimes found, especially in the upper beds. There are many veins of calcium carbonate running through the clay and there is a little silicified wood. The Frio Clay Formation varies from 175 to 800 feet thick in our area. These sediments were deposited in lagoons along the

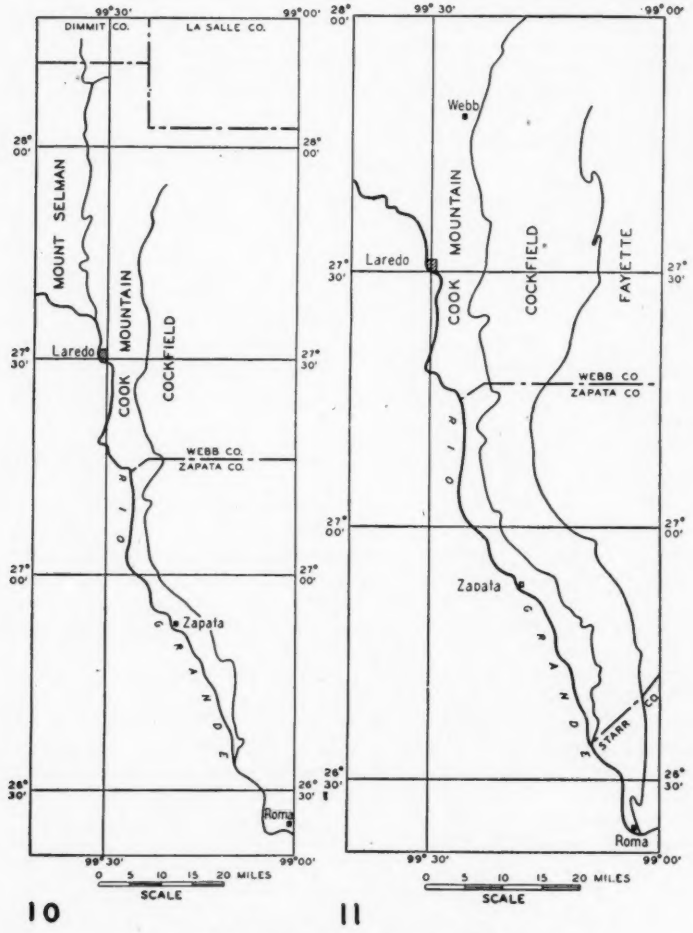


Fig. 10. The outcrop of the Cook Mountain Formation.
Fig. 11. The outcrop of the Cockfield Formation.

shore line during the late, Eocene, Oligocene, or early Miocene. The uniformity of the deposits indicate uniform conditions or rapidity of deposition. A small quantity of volcanic ash is mixed with the clay, which probably came from volcanoes without this general region.

MIOCENE SERIES

Oakville.—The Oakville Sandstone outcrops at the surface in the Lower Rio Grande region is only a few places because of the extensive overlapping by the Reynosa Formation. The only exposures which may be positively identified occur along the west face of the Bordas Escarpment in the general area mapped in Fig. 14. There are a number of small outcrops westward of the Reynosa Formation that do not appear in the figure. The rocks are conglomerate, gritstone, sandstone, clay, and volcanic ash. There have been no fossils found in the Lower Rio Grande exposures of this formation. The sandstone, clays, and siltstone of the Oakville Formation were deposited by fresh water as fluviatile sediments in broad shallow valleys which had been previously developed on the Frio Clay Formation. These deposits finally filled these valleys and spread in continuous sheets over the intervening low ridges. The volcanic ash came from volcanoes outside of this region.

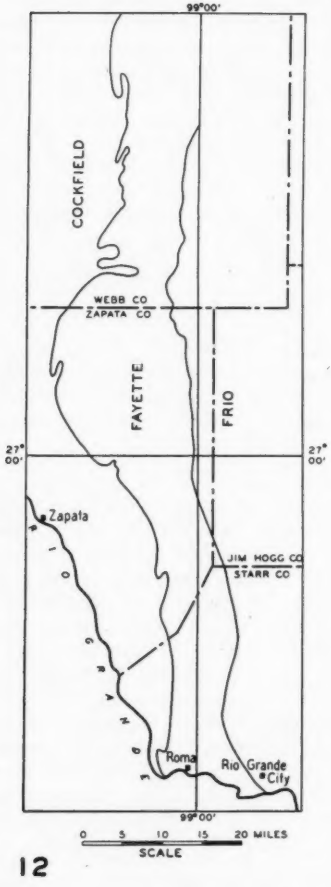
PLIOCENE SERIES

Lagarto.—The Lagarto Clay appears below the Reynosa in the Rio Grande bluffs west of Sam Fordyce, in the southwestern corner of Hidalgo County. Half a mile west of Sam Fordyce, an 18-foot bed is exposed in a gravel pit. It is composed of a heavy, stiff, sandy or silty calcareous clay. It is a fresh water, fluviatile deposit.

Reynosa.—The Reynosa Formation forms the base of the Bordas Escarpment, from which it dips eastward forming an outcrop 35 to 45 miles wide in Webb, Jim Hogg, Starr, Brooks, and Hidalgo Counties. The eastern boundary is indicated in Fig. 15. Wind blown sand obscures its surface features over considerable areas. Westward of the Bordas Escarpment, the Reynosa overlies unconformably all the older Tertiary Formations, and further westward it overlaps the Upper Cretaceous. These strata are composed of mixtures of gravel cemented by calcium carbonate, limestone, sand, sandstone, and a little clay. There is silicified wood in that part which overlies the Fayette and Oakville Formations. The sand and sandstone weathers to a dark red sand, the grains of which are quartz, coated with red iron oxide. In some places, the red coating has been worn off by wind. The sandstone material of the Reynosa deposits weathers typically to red, pink, or gray sand, through which white or gray limestone frequently projects. The depth of the Reynosa Formation has not been determined with accuracy. West of the Bordas Escarpment, it is not more than 30 feet thick.

After the deposition of the Oakville Sandstone and probably also the Lagarto Clay, the plain of southern Texas was slightly elevated, tilted and eroded to a peneplain. This peneplain may have txended as far west as the

mountains of Trans-Pecos. The surface became covered with products of weathering such as sand, clay, and remnants of silicified wood. Then, probably in the Pliocene, the Balcones Fault became prominent. The western part of this great level plain was elevated as the eastern part was lowered. This higher land caused increased rainfall which resulted in the rejuvenation of streams. Erosion continued until the unweathered substrata were cut, and there was a great gulfward transport of materials. Ground water also moved gulfward



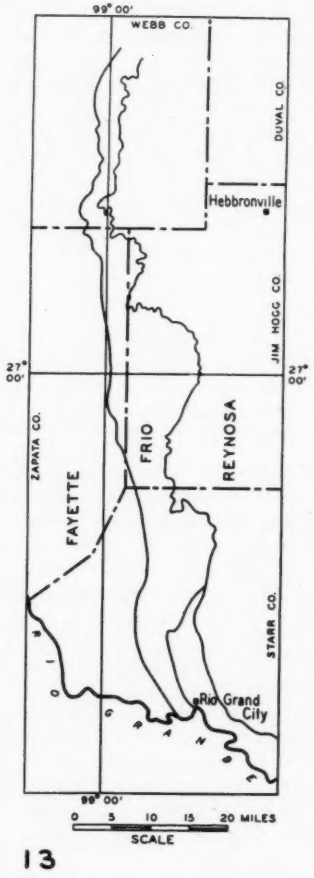


Fig. 12. The outcrop of the Fayette Formation.
Fig. 13. The outcrop of the Frio Formation.

carrying large amounts of calcium bicarbonate and other salts. Finer sediments were moved onward to the gulf, while coarser gravels remained to form the Reynosa gravel beds. Most of the pebbles of the gravel and conglomerate come from the Edwards Plateau. The quartz and igneous rocks were brought by the Rio Grande from the Cordilleran Mountains of Trans-Pecos and beyond. The limestone was mostly formed by ground water seepage to the surface. Continuous erosion together with the eastward transportation of materials, caused a thinning of the western margin of the Reynosa deposits, and a consequent thickening gulfward. The seaward margin dips below the Quaternary sediments and merges into marine deposits of the same age. This Reynosa Formation has been called Uvalde by some geologists.

QUATERNARY SYSTEM

PLEISTOCENE SERIES

Lissie.—The Lissie Gravel Formation has been called the Equus Beds or Columbia (in part) by some geologists. It outcrops in a belt 8 to 12 miles wide in Hidalgo County as shown in Fig. 15. It appears again in Brooks

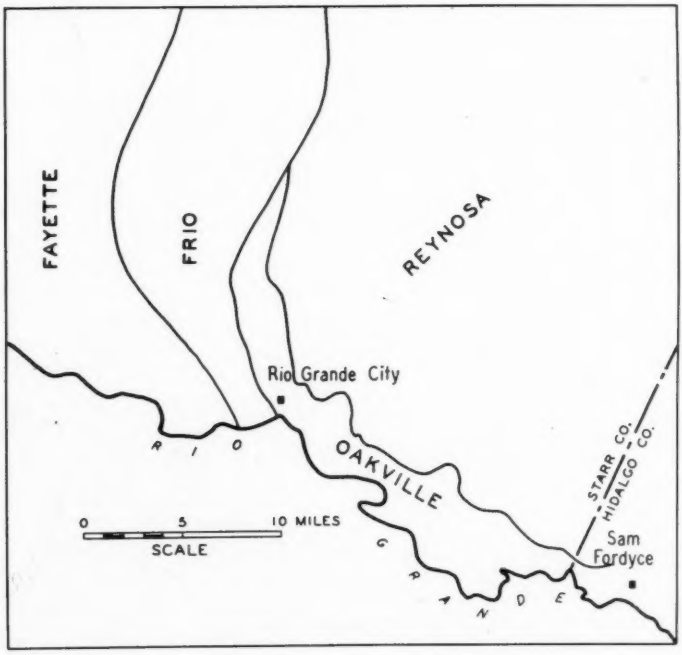


Fig. 14. The outcrop of the Oakville Formation.

County, the intervening section is covered with wind-blown sand. The Lissie Gravel resembles the Reynosa Formation. It differs primarily in its larger proportion of unconsolidated gravel and the smaller proportion of limestone. There is a little sand and thin, superficial beds of caliche. It weathers to dark gray or black loamy soils. Its thickness is undetermined in our region. Further north it ranges from 493 to 1020 feet in thickness. The Lissie Gravel deposits were derived from the Reynosa and were deposited by streams.

Beaumont.—The Beaumont Clay Formation has been called Port Hudson by some geologists. It agrees in age with the Columbia group of the Atlantic Coast. Its area is now covered by windblown sand for about 50 miles southward from the northern border of the Lower Rio Grande region. Further west, it is covered by younger clays and sand deposited by the Rio Grande as part of its present delta. It appears in the northern part of Hidalgo County in a narrow strip where it has been left exposed by migrating sands. In the southern part of Hidalgo County, it occurs above the high water mark of the Rio Grande as shown in Fig. 14. It is composed of blue, or red calcareous clay, which weathers to a yellowish color. The soils developing from it are usually dark-gray, clay loams, overlaid in their undisturbed condition by a thin layer

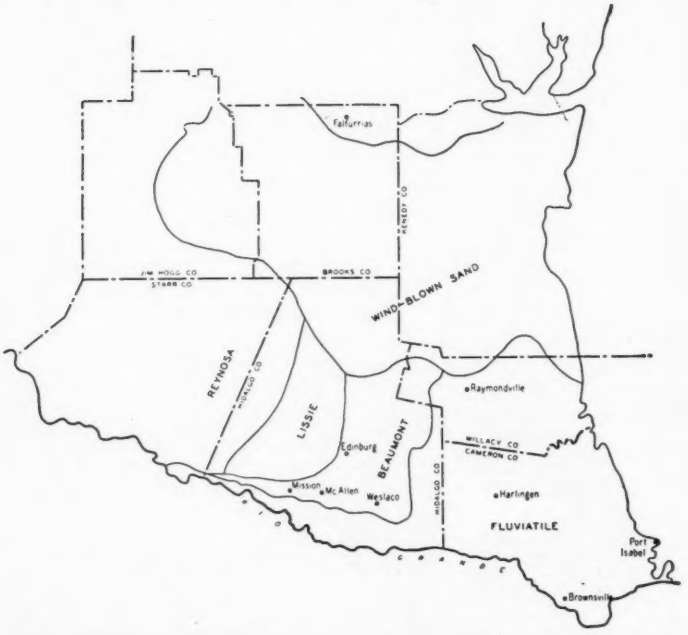


Fig. 15. The outcrops of the Reynosa, Lissie, Beaumont, Fluviatile, and Wind-blown Sand Formations.

of drifting sand. Its thickness has not been determined in our region, although farther north, estimates of 300 to 900 feet have been made. These clay sediments were deposited in estuaries and coastal marshes. The eastward margin as observed in well borings is of marine origin. The shore line has retreated eastward 35 to 40 miles since its deposition. This formation was caused by a submergence of the coast plain which caused the streams to form ponds with a consequent filling of their valleys with the finer sediments.

Terrace Deposits.—There is a series of river terrace deposits along the Rio Grande and some of its larger tributaries which have been called Leona by some geologists. Below the southwest corner of Hidalgo County near Sam Fordyce these terraces give way to the present erosional flood plain. They are composed of gray or buff-colored silt, together with a little sand and fine gravel. The cities of Laredo, Zapata, and Rio Grande City stand on these Pleistocene river terraces. About 2 miles southwest of Sam Fordyce, there is a terrace 15 feet above the Rio Grande which is flooded during high water. There is a second terrace 200 yards from the river which rises 20 feet above the river and is about 100 yards wide. A third terrace, the main one, is 30 feet above the river and is a mile wide.

RECENT SERIES

Fluviatile Deposits.—This is the area near the mouth of the Rio Grande which is subject to flooding. These deposits are mapped in Fig. 15. They are being built up at the present time by these overflows. Mission Ridge, a part of the Beaumont Formation, is above flood level, and has been used for the highway and railroad. The towns of Mission, McAllen, Pharr, San Juan, and Donna have been built on this higher land. This area was reclaimed from the Gulf by river-deposited sediment, and therefore the lower beds are marine and only the upper beds are of Recent fluviatile origin. Clay is the most important component. It is highly calcareous, colored gray, blue, red, or brown. Cross checks are filled with calcium carbonate, sand, and silt. At Rio Hondo, the channel of the Rio Colorado is 23 feet deep which exposes the reddish-gray and yellowish-gray sandy clay of this formation.

Wind-blown Sand.—Figure 15 shows a conspicuous area of shifting sand covering most of Kenedy, Willacy, Brooks, and the northern part of Hidalgo and the eastern part of Jim Hogg Counties. This sand is usually gray or white, but is red or pink especially where it overlies the Reynosa Formation. Much of this sand was blown inland from the coast, but a large part was derived from the weathering of the underlying Reynosa and Lissie Formations. Blow-holes expose the reddish-brown sand of these underlying formations.

Coastal Deposits.—Padre Island is a densely covered island, 1 mile or less wide. Shore deposits are being laid down on the gulfward side.

Physiography

The essential natural features of any area are more clearly comprehended if they be viewed in relation to the physiographic province of which the area

forms a part. Also, the characters of any particular physiographic province themselves become more comprehensible if they are considered in relation to the surrounding provinces. A brief description of the physiographic provinces of the state of Texas, therefore, will assist the reader in orienting himself in respect to the general aspects of the Lower Rio Grande Valley which are influential in governing the agricultural characteristics of the region.

Three of the great Physiographic Provinces of North America extend over the Texas area. The southern extension of the Great Plains covers the central and northern parts of the state, the Western Cordilleras approach from the northwest and include the country west of the Pecos River, and the Atlantic and Gulf Coastal Plain sweeps around the Gulf of Mexico to include the coastal area of the State. Authors variously subdivide these three major continental provinces into smaller units based on local characters of soil, climate, geologic structure, drainage systems, underground water conditions, and general environment for human life. In fact, we may subdivide the Texas region into smaller areas on the basis of a great many viewpoints. A "country," or a subdivision of a province, is defined on the basis of some particular and localized feature of the soil, flora, or topography. Hence we may correctly refer to the Coastal Prairie Country of the Southern Texas Province. Plant ecologists recognize a scheme of extensive subdivisions of a Province into Subprovinces, Divisions, Subdivisions, Districts, Subdistricts, Landscapes, Land Forms and Habitats. Only the major units will be described in the present paper.

The earlier terminology applied to Texan physiographic provinces is very confusing to the uninitiated. For example, "Southwest Texas" does not refer to the southwestern part of the state, but merely designates the area reached by early settlers after they had travelled south and west from their original eastern homes. The old "Southwest Texas" of history and romance in reality is the present "South Texas."

As early as 1891, Hill (5) recognized that the eastern half of Texas was made up of a series of ancient dip plains composed of vraious strata dating from the Comanche to Recent. This vast coastward incline included the Coastal Prairies (Pleistocene), Washington Prairies (Miocene), Eolignitic or Forested Region (Eocene), Main Black Prairie (Upper Cretaceous), Grand Prairie (Comanche or Lower Cretaceous), and the 2 belts of Cross Timbers (bases of the Upper and Lower Cretaceous respectively). The Central Denuded Region was defined as rock sheets of Paleozoic and early Cretaceous (Red Beds), which dip westward unconformably below the coastward incline and also below the Llano Estacado.

The Washington Prairies were described as the region of rich black earth westward of the Coastal Prairie. The soils were derived from friable sandstone, of the Fayette Formation, which was composed of well rounded polished grains of quartz cemented by a whitish calcareous matrix. These strata are waterbearing, and they dip below the coastal clays and supply the Coastal Prairie with artesian water.

The Rio Grande Embayment was the low area south of the Balcones Escarpment, reaching inland along the Rio Grande as far as Eagle Pass. It is made up of the southern extensions of the Coastal Prairies, Washington Prairies, Timber Belts, and the Black Prairie.

An early map of the physiographic provinces of Texas published by Hill and Vaughan (7) is reproduced as Fig. 16. The major areas recognized at this time were Trans-Pecos, Stockton Plateau, and the Plateau of the Plains. This last was subdivided into the Llano Estacado and the Edwards Plateau, the Central Denuded Region, East Texas Timber Belt, and the Coastal Prairie. The Rio Grande Plain was regarded as the area southward of the Balcones Escarpment and the Colorado River. It was composed of the southern extension of the Black Prairie, East Texas Timber Belt, and the Coastal Prairie. The wide and extensive indentation of this plain inland along the Rio Grande had been previously described by Hill (5) as the Rio Grande Embayment. The Black Prairie is underlain by the soft Upper Cretaceous chalky limestone and marly clays. Considerable rainfall on these strata has caused the development of some of the most valuable agricultural land in Texas.

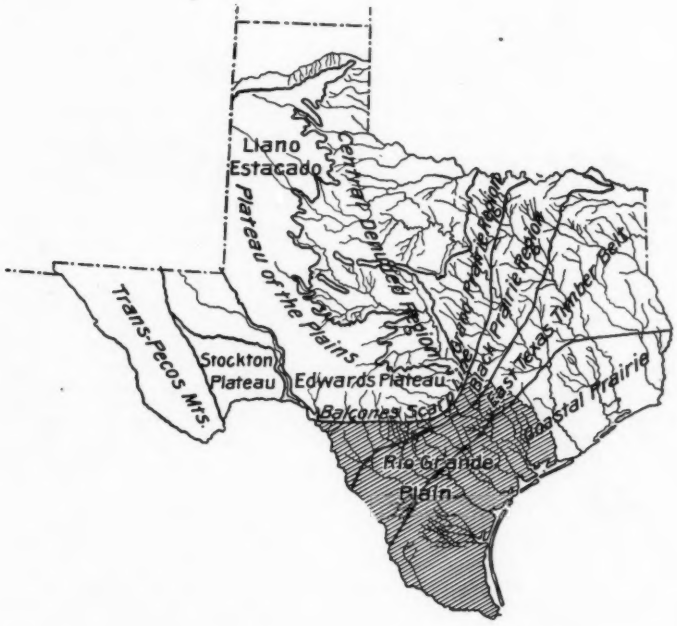


Fig. 16. Physiographic provinces of Texas (Hill and Vaughan 1896-1897).

Hill (6) later published a map on which he divided Texas into six provinces—Trans-Pecos, Great Plains, and the Central, East Central, Eastern, and Southern plains. Figure 17 has been reproduced from this early map. Trans-Pecos is an extension of the eastern ranges of the Cordilleras, although the province included plateaus, plains, and interior basins as well as mountain ranges. The western half of Trans-Pecos belongs to the continental Cordilleran Province. It is composed of low mountains, plains, and basins. The mountains are broad and plateaulike, and for this reason some authors regard them as a part of the Colorado Plateau Province. There are three main ranges, all of which run northward into New Mexico. The two easternmost of these cross into Mexico, and deep gorges are cut through them by the Rio Grande.

The most eastern of these ranges is called the Front Range of the western Cordilleran system. It enters from New Mexico as the Guadalupe Mountains. It contains the famous Carlsbad Caverns in the southeast corner of New Mexico. In Texas, this range contains the Davis Mountains and the Sierra del Carmen. The Sierra del Carmen extend into northern Coahuila. On the Texas side of the Rio Grande, they are separated from the Davis Mountains by the Salt Basin. There are a few mountains of minor importance eastward

Fig. 17. Physiographic provinces of Texas (Hill 1899).

of the Front Range proper. The second range to the westward is the Diabolo Plateau which enters Texas from the north as the Hueco Mountains and from the southeast as the Cornudas Mountains. It is deeply trenched by the Rio Grande where it crosses in northern Mexico. The third range to the westward is made up of the Franklin Mountains. They extend from near El Paso northward into New Mexico and are separated from the Diabolo Plateau by the Hueco Bolson. These three ranges of Trans-Pecos are the result of two great anticlines, one of which is the Front Range, and the other the Franklin Mountains. The Diabolo Plateau is the syncline between them.

The Great Plains Province is an extension of the Great Plains proper of the interior of the continent. The Llano Estacado is the northern part of this province. It is a great constructional plain of terrestrial deposits on a much older destructional or eroded plain. The Edwards Plateau forms the southernmost area of the Great Plains Province. It is a destructional plain produced by long continued erosion.

The Central Province is composed of a variety of prairie plains, which are sometimes referred to as the Central Denuded Region. The features of these prairie plains are arranged in more or less north-south belts. The East Central Province is made up of the Black Prairie, Grande Prairie, Western Cross Timber, and Eastern Cross Timber Countries. The Eastern Province is the northern half of the Texas Coastal Plain. In general, it is the forested area eastward from the Black Prairie Country. The Southern Province is the southern half of the Texas Coastal Plain. It is made up of a group of diverse Countries such as the Coast Prairie, Fayette Prairie, Carrizo Country, which is the attenuated southwestern extension of the Atlantic-timber belt, the Comal Country, which is the southern extension of the Black Prairie, and the Rio Grande Embayment.

The Coastal Plain, as designated by Hill, is a region of great interest to the student of soil development. It is a very large area embracing both the Eastern and Southern Provinces. Its outline coincides closely with Tertiary and Quaternary deposits resting on the much older Cretaceous. This vast and agriculturally valuable plain is composed of three main types of country, the Coastal Prairie, East Texas Timber Belt, and the Rio Grande Embayment. The Coastal Prairie is a nearly level constructional plain, newly recovered from the Gulf by deposition and by a gentle uplift of the land. It extends for about 50 miles into the sea, forming a zone of shallow water along the coast. Physiographically, it is young, and a typically youthful drainage system is being established on it. The East Texas Timber Belt is sandy timber land, which corresponds in extent to the outcrop of Eocene strata. Its physiographic character could be described as that of a dissected dip plain. The Rio Grande Embayment is the Rio Grande Country lying southward of the Balcones Escarpment and extending south and southeast to the Rio Grande. It is the Texas side of a low synclinal trough between the Balcones Escarpment and the Mexican mountains on the south. Since Cretaceous time, this area has been repeatedly submerged and elevated. A description of the succession of strata which were deposited during this period of successive submergences and

elevations is included in the section on geology. These strata have a direct bearing on the soils that have been developed from them in the Lower Rio Grande Valley.

About 16 years after the publication of Hill's map of the physiographic provinces, Udden, Baker, and Böse (15) presented a physiographic map which is reproduced in Fig. 18. Baker agreed essentially with Hill, although he recognized more subdivisions of the Provinces. For instance, he divided the Continental Great Plains into the High Plains of the Panhandle, Llano Estacado, Central Mineral Region, Edwards Plateau, Grand Prairie, Trans-Pecos Plains, and the North Central Plains.

The report by Trowbridge (14) recognized the following physiographic provinces in Texas: The High Plains, Osage Plains, Mexican Highland, Sacramento Section, Pecos Valley, Central Texas Section, Edwards Plateau, and the West Gulf Coastal Plain. The shaded area of Fig. 19 was designated as the Lower Rio Grande.

The most detailed and complete statement of the physiographic provinces and their subdivisions was published by Johnson (8). This author retained

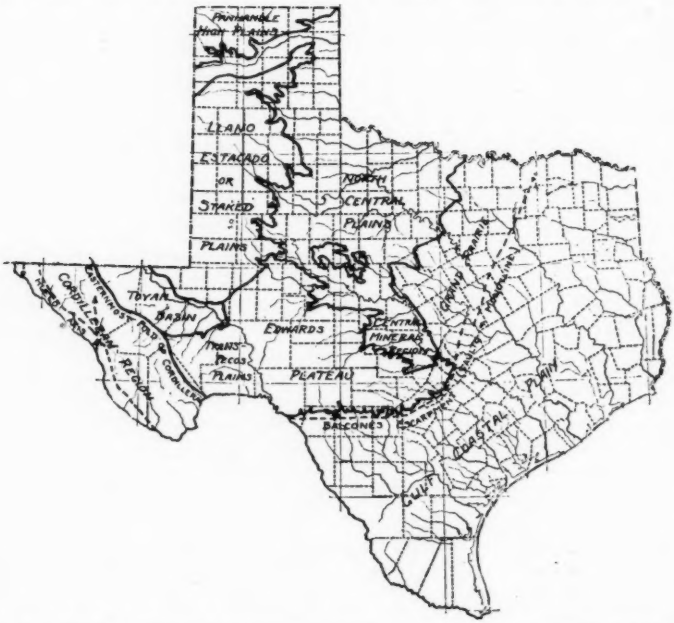


Fig. 18. The principal physiographic regions of Texas (Udden, Baker, and Böse 1916).

the teminology of Baker, but he grouped the provinces as is indicated in Fig. 20, into four major provinces, which he designated as the East Texas Plains, the Texas Prairies, Middle Texas Province, and the Western High Plains. Each of these were subdivided into a great many smaller areas. These subdivisions present a very clear picture of the agriculturally significant sections of the state. The South Texas Plains include the area between the Balcones Escarpment and the Gulf Coast. The boundary extends slightly east of south from the point where the escarpment approaches the Colorado River and reaches the Gulf Coast east of Corpus Christi Bay. The 14 subdivisions of the South Texas Plains are indicated in Fig. 21 as follows:

Cc-1. Western Extension of Southern Black Prairies. This area is underlain by shallow caliche beds.

Cc-2. Southern Black Prairies. These prairies are of the Black Earth type. The area is a lowland developed by the erosion of the soft strata. The surface is rolling, and several streams from the Edwards Plateau cut across it on their way to the Gulf, leaving low, wide valleys, covered with alluvial deposits. These rich valleys were among the first lands to be cultivated by the early settlers in Texas, and they were important factors in the early develop-

Fig. 19. The relation of the Lower Rio Grande region to the physiographic divisions of Texas (Trowbridge 1932).

ment of the city of San Antonio. These prairies overlie the Cretaceous and basal Tertiary strata. The strata outcrop along the interior margin of the area.

Cc-3. Plains Strips on Sands and Sandstone Material. This is the southwestern extension of the deciduous forest which characterizes the country east of the Black Prairie. Southwestward, the forest fades gradually and is replaced by mesquite and chaparral. The surface is rolling, and it is cut across by several streams from the Edwards Plateau. The resulting valleys are filled with alluvial deposits, and are well watered. There are large areas of gravel which are outcrops of the Uvalde Formation. These outcrops are covered with a dense growth of chaparral. It is probably from these centers that the chaparral spread into surrounding areas when the early settlers disturbed the natural ecological factors that dominated the original vegetation.

Cc-3a. Modified Extension of the Plains Strips on Sand and Sandstone Materials.

Cc-4. Interior Coastal Prairies. This is a comparatively well marked belt of slightly rolling lowland which has been developed on strata of outcropping limestone and calcareous clay. It represents a southwestern extension of the

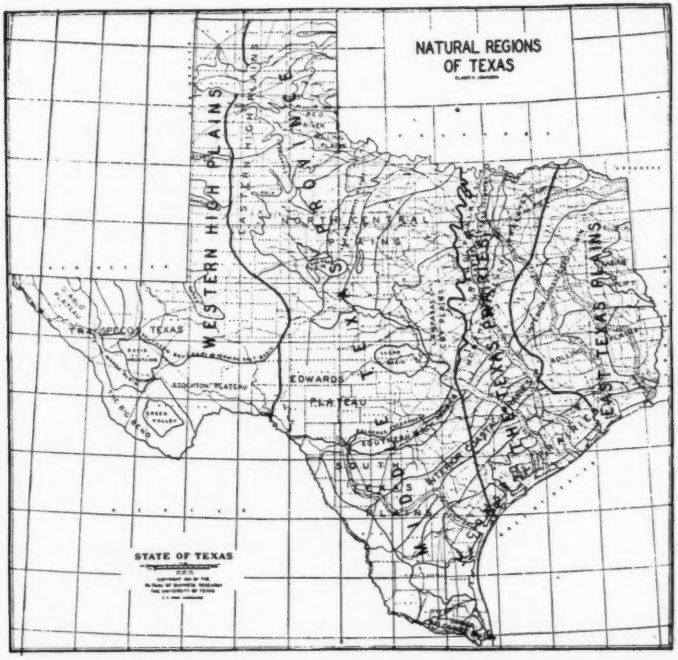


Fig. 20. Physiographic regions of Texas (Johnson 1931).

Interior Coastal Prairies from the east. Originally, it was covered with Tall Grass, but since the colonization has taken place, chaparral and prickly pear are increasing. The climate is subhumid. The soil is black, fine in texture, and calcareous. Some of the lower land has been covered with alluvial material, which develops the blackest soil in this area. Caliche underlies the drier sections.

Cc-5. Mixed Grassland and Chaparral Strips. This area has been dissected to give a rought topography. There are extensive boulder deposits which are commonly covered with dense craparral. Over-grazing has permitted the extension of the chaparral into the grassland. The soil is underlain by a shallow layer of caliche.

Fig. 21. The physiographic subdivisions of the South Texas Plains (redrawn from Johnson 1931).

Cc-5a. Upland Plains of the Lower Rio Grande Valley. This area forms the most valuable agricultural area of the Lower Rio Grande Valley. It is a southern extension of the Coastal Prairie. The soils are dark to black except where the sand content is high. The dark color was developed under the former grass cover. The soils differ from those of the Black Coastal Prairies (Cc-7) by their greater dryness and the higher sand content of the underlying material. The vegetation is mesquite, chaparral, and prickly pear, which has extensively replaced the original grass cover. This comparatively small area forms the "Magic Valley" which has figured so prominently in the advertising campaigns of land promoters.

Cc-5b. Southwestern Extension of the Mixed Grassland and Chaparral Strips (Cc-5).

Cc-6. Marginal Coastal Prairies. This region is twpical of the Coastal Prairies generally. It is more rolling, and although the soils of the southern part are black, they are not similar to those of the true Coastal Prairire. The northern part has soils lighter in color because of greater leaching. The subsoil is heavy clay which seriously impedes the circulation of surface water.

Cc-7. Black Coastal Prairies. This area is a constructional plain underlain by fine-textured limy material. The climate is subhumid, and the tall-grass cover has developed black soils. Consequently the former cattle ranching is now giving way to intensive vegetable and cotton farming.

Cc-8. Plains With Deep Sands. Here there are deep accumulations of

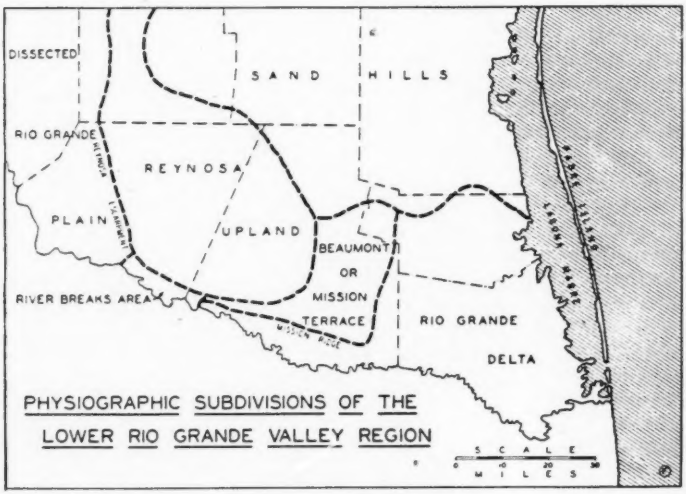


Fig. 22. The physiographic divisions of the Lower Rio Grande Valley (Foscue 1932).

sand which has been carried inland by wind. Generally, there is a layer of hard caliche at a depth of several feet. Scrubby Live Oaks form the dominant vegetation. The soil is infertile and cattle ranching is the main industry of the area.

Cc-9. Eroded Plains Marginal to the Rio Grande. The "Breaks" of the Rio Grande occur along the riverward margin of this area.

Cc-10. Transitional Area Between the Upland Plains of Lower Rio Grande (Cc-5a) and the Plains with Deep Sands (Cc-8).

Cc-11. Alluvial Lands of Lower Rio Grande Valley. This is the "Delta" area of the Lower Rio Grande Valley. Its character is determined y the nature of the deposits left by the Rio Grande as its course migrated to the south-

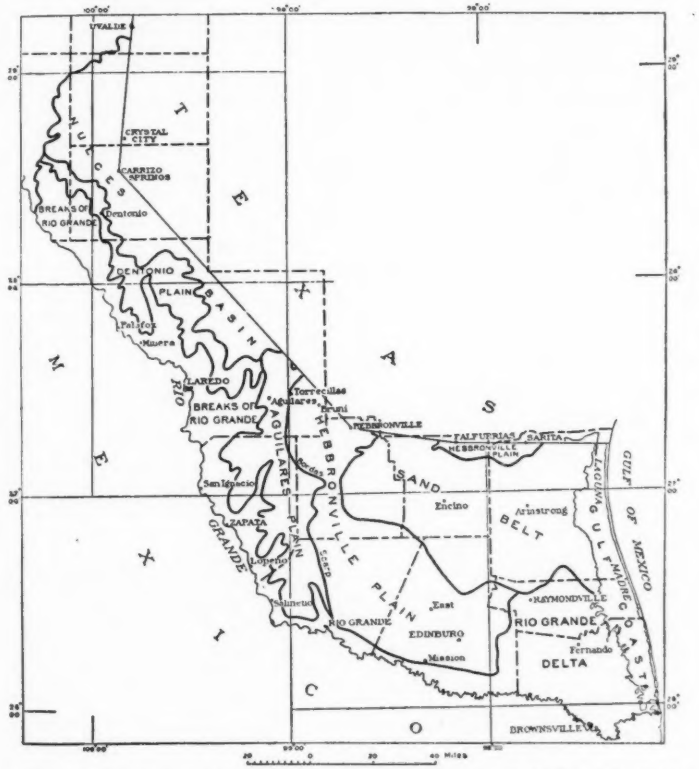


Fig. 23. The physiographic divisions of the Lower Rio Grande Valley (Trowbridge 1932).

ward during the past. Natural levees along some of these old channels are still evident and they are covered with coarse silts and sands which permit moderately good drainage. The lower areas between the levees are heavy clay and are poorly drained. Eastward, towards the mouth of the Rio Grande, the original alluvial deposits have been extensively reworked, partly by the sea, partly by wind.

The physiography of the Lower Rio Grande Valley was studied in considerable detail by Foscue (3). The subdivisions described by this author appear in Fig. 22. They correspond closely to related groups of soil series, and they are of particular value as a basis for interpreting the development of the soils of this area. The Dissected Rio Grande Plain is the most westward of the true Lower Rio Grande region. It is flat, but is cut with arroyo channels. The Breaks along the Rio Grande begin where the Rio Grande cuts across the Reynosa Escarpment and extend down the river until it emerges on the eastern edge of the Reynosa Upland. This is a narrow deeply dissected area along the Rio Grande, formed by a youthful drainage system cutting a series of short valleys in the riverward margin of the resistant strata of the Reynosa Formation. Along the highway from Mission to Rio Grande City it appears as a series of ridges and valleys that often extend almost to the bank of the Rio Grande. The ridges are capped by Renosa strata. The Reynosa Upland is a flat dip plain sloping gently towards the Gulf. This is the area irrigated generally by the 'third lift" pumps of the local irrigation system. The Mission Terrace is a level, gently rolling plain somewhat lower than the Reynosa Upland. Its area corresponds locally to the exposure of the Beaumont Clay Formation, an old flood plain of the Rio Grande, deposited during the Pleistocene. Along its southern border there is a pronounced slope from the terrace level downward to the present flood plain. This slope is called "Mission Ridge." Land in this area is irrigated by "second lift" pumps. The Rio Grande Flood Plain begins about at the Starr-Hidalgo County boundary line and forms but a narrow strip along the river until Mission Ridge is passed, then it widens rapidly until it becomes 40 miles wide at the coast. Until the present flood-control channels were constructed, this area was frequently overflowed by the Rio Grande. It is irrigated by "first lift" pumps. It is particularly evident after comparing Figs. 22 and 23 with the geologic maps of outcropping strata that the physiography of the Lower Rio Grande is intimately related to the underlying geologic formations.

The Lower Rio Grande was further subdivided by Trowbridge (14), although its structural features are much obscured by drifting sand and delta deposits. The subdivisions recognized by this author are more technically accurate than those of other authors. The Bordas Escarpment is the most conspicuous topographic feature of the area. The subdivisions recognized are the Breaks of the Rio Grande, Nueces Basin, Dentonio Plain, Aguilares Plain, Bordas Scarp, Hebbronville Plain, the Sand Belt, the Rio Grande Delta, and the Gulf Coast. These subdivisions are indicated in Fig. 23.

The Breaks of the Rio Grande begin at the Cretaceous-Eocene line of contact and continue downstream to the vicinity of Peñetas, at which point

the present erosional valley of the Rio Grande begins. The Breaks is a series of shallow valleys, scarcely averaging 15 miles in length, that lead from the upland plain to the Rio Grande. This belt is from 1 to 15 miles wide. It is roughly divided topographically into north-south belts because of differences in the erosional character of the outcropping formations. The westernmost of these belts from the Cretaceous-Eocene line to San Ambrosia Creek exhibits a subdued surface controlled by the relatively nonresistant, homogneous Indio Formation. The Midway exposure is so narrow that it causes no significant surface feature. The Carrizo Sandstone Formation is more resistant and forms a west-facing escarpment. The Bigford Formation lies between this Carrizo ridge and the mouth of Espada Creek. Its lenses of sandsotne in clay and shale give rise to an unusually irregular topography. Between Espada and Sambarieto Creek the Mount Selman Formation forms the surface. Its beds and lenses of hard sandstone in clay form bluffs along the river, but appear as small mesas and small but rugged canyons away from the river. From about 8 miles above Laredo, downstream to Ramireno, the Rio Grande parallels very closely the strike of the Cook Mountain Formation. These strata are unusually resistant to erosion and consequently the topography is rugged. Between Ramireno and Roma the Cockfield Formation causes a low relief. From Roma to Rio Grande City, the Breaks cut through the Fayette, Frio, and Oakville Formations. The Fayette forms westward-facing cuestas, the Frio Clay forms low, gentle river bluffs and wide, open valleys. The Oakville forms the lower slopes of bold bluffs. The Reynosa Sandstone Formation forms a resistant cap to the Breaks from Rio Grande to Sam Fordyce, resulting in a mesa-like topography. Below Sam Fordyce, the Lissie Gravel Formation forms bluffs which become progressively lower downstream until they disappear. The Breaks of the Rio Grande expose one of the finest series of coastal Tertiary and Quaternary strata in North America.

The Nueces Basin is the section drained by the Nueces River. It is partly filled with Pleistocene silt, which results in wide valleys.

The Dentonio Plain is a narrow and irregular highland which separates the drainage system of the Nueces River from that of the Rio Grande. This is an area with little or no drainage system. It is sandy, level, and bears an open scattered prairiegrass vegetation. There is almost no brush.

The Aguilares Plain lies between the northern boundary of our region and Rio Grande City, and between the Breaks of the Rio Grande and the Bordas Escarpment. It drains into the Rio Grande, but the drainage system is shallow, and therefore distinct in appearance from that of the Breaks. It slopes gently southward and eastward. The surface is flat or very gently undulating. The underlying Cockfield Formation weathers to produce dark gray or black soils. Short-grasses form the predominant vegetation. Mesquite and Prickly Pear are rare.

The Bordas Escarpment follows generally the outcrop of the base of the Reynosa Formation. It slopes steeply westward and gently eastward. It is broken into a series of mesa-like hills which are conspicuous if viewed from the west.

The Hebbronville Plain is a cuesta of which the Bordas Escarpment forms the western edge. It is aout 60 to 70 feet higher than the Aguilares Plain. It is slightly dissected, and wind has roughened the surface in many places. Generally, it is nearly flat. The soils are sandy, and there are many exposures of white limestone.

The Sand Belt is an area of almost 3,000 square miles. The bedrock in many places is covered with wind-blown sand. Sand dunes form and migrate with the wind at many places.

The Rio Grande Delta is the region referred to locally as "The Valley." The surface is flat except for some low "clay buttes." The soils are sandy, silty, or clayey.

The Gulf Coast includes the mainland shore and the narrow dune-covered sand barrier named Padre Island. It reaches from Corpus Christi to the mouth of the Rio Grande. It is less than one mile, and it lies 4 to 10 miles off shore.

Summary

1. The Cenozoic formations of the Lower Rio Grande Valley and their relationships to the general geologic structure of the Texas area are described.

2 .The physiographic subdivisions of the Lower Rio Grande Valley and their relationships to the larger divisions of Texas are briefly reviewed. The association of physiographic features with geologic structure is emphasized.

3. The geologic and physiographic characteristics of Texas exert powerful influences on the development of the soil series and vegetation. This is especially evident in the Lower Rio Grande Valley. A knowledge of the geology and the Physiography are essential prerequisites to the study of the soils and vegetation of Texas.

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The Vegetation of the Mount Livermore Area in Texas

L. C. Hinckley

Introduction

The Mount Livermore area is geologically a part of the Front Range of the Western Cordilleras, a system which reaches its easternmost extension in the United States within that section of western Texas known as the Trans-Pecos Region. Livermore itself is the highest point in the Sawtooth Range of the Davis Mountains, a small system originating in deformational movements during late Cretaceous time. Succeeding periods of erosion, lava flows, other deformational movements, and the severe erosion of recent time have formed a lava canyon region covering several hundred square miles.

Baker and Bowman (1917) describe the Sawtooth Range as a broad, low anticline of intrusive porphyritic syenite. The major axis of the range has a general northwest-southeast direction, Mount Livermore occupying almost a middle position. The whole range probably marks a line of fissure eruptions of which the cliffs of the highest peak are typical examples (Fig. 1).

Previous Botanical Research

Early botanical work in the Livermore area was concerned chiefly with collections and descriptive writings. Sponsored by Gray (1850-52), Wright made two collecting trips through the Davis Mountains, accompanying a military wagon train from San Antonio to El Paso in 1849 and as a member of the Graham Boundary Survey on its return from the West in 1852 (Wooton, 1906). Two other members of the U. S.-Mexican Boundary Expedition, Bigelow and Schott, secured specimens in Limpia Canyon of the Davis Mountains, according to descriptions of the plants of the expedition made by Torrey (1858) and Engelmann (1859). Havard (1885) and Neally (1888) included descriptions of some of the plants of the Davis Mountains in their accounts of the vegetation of the Southwest, and Coulter (1891-94) compiled all of these early descriptions in a manual of the flora of western Texas.

Investigations made since 1900 have dealt more with the ecological phase of botany. Bray (1901, 1906), in the first wholly ecological treatise of the vegetation of the Southwest, discussed climatic and edaphic factors and described the region as the meeting ground of several life zones. Dr. M. S. Young left unpublished notes in the botany department of the University of Texas dealing with an ecologic and taxonomic study of vegetation of the Livermore area in 1914 and 1918. In the only published article wholly concerned with the vegetation of the Davis Mountains, Palmer (1929) inferred that the colonies of ligneous plants are relics of a once more or less continuous flora which covered most of western North America.

Present Work

The present work has attempted an intensive survey of the vegetation of Mount Livermore and its immediate vicinity. The field work was begun in

September, 1934, and was continued at intervals until October, 1939. Most of the work was done in summer and fall; but occasional trips were made during spring, early summer, and winter months.

Precipitation

The amount of precipitation for the Mount Livermore area was estimated from a study of the records kept at Fort Davis, which is about twenty-five miles southeast of Mount Livermore, and those of McDonald Observatory on Mount Locke 9.5 miles almost east of the higher peak. The Fort Davis records, kept intermittently since 1855, show an average annual precipitation of 16.48 inches (Table 1). The five-year records of McDonald Observatory show an average about 3½ inches greater than that at Fort Davis, or about twenty inches.

Since the higher average is probably due in part to the difference in elevation, 6790 feet on Mount Locke as compared to about 4800 feet at Fort Davis, it seems safe to assume that the annual average on Mount Livermore is at least twenty-five inches. Observations also tend to prove that the precipitation is greater on the higher peak, elevation 8382 feet, for clouds often are seen to accumulate over its summit when skies elsewhere are cloudless.

The monthly averages for the period of the records indicate that about one-half of the precipitation occurs during the months of July, August, and September (Table 1); and about three-fourths occurs during the months from May through September. It would seem then that the growing season is limited to about six months.

Temperature

Though the Davis Mountains lie between the thirtieth and the thirty-first parallels, the mean temperatures are comparatively low. The mean annual temperature at Fort Davis for the twenty-nine years covered by the records is 60.8° (Table 2). The five-year record of McDonald Observatory shows the mean annual temperature to be 56.9°, about four degrees lower than that of Fort Davis. By comparing the mean annual temperatures of Fort Davis and Mount Locke, one may assume that the mean annual temperature of Mount Livermore is about fifty degrees.

Frost data for Fort Davis and Mount Locke indicate an average length of time between killing frosts of about 210 days for the former and 200 days for the latter from the latest freeze in spring to the earliest freeze in autumn. By inference again the average length of time between killing frosts from spring to fall on the upper slopes of Mount Livermore is somewhat less than 200 days, probably about six months. It would seem then that low temperatures as well as seasonal rainfall might limit the growing season to about six months. Both factors are unpredictable in this area.

Topography

The Mount Livermore area is a region of rough, broken terrain consisting of an east-west ridge with the peak as the apex and canyons originating on all sides of the oblong summit (Figs. 1 & 2). On the north and northwest are

TABLE 1.—Precipitation: Average Monthly and Annual Amounts in Inches and Hundredths.

Station	Record in years	January	February	March	April	May	June	July	August	September	October	November	December	Annual
Ft. Davis	62	.49	.47	.34	.58	1.23	1.79	3.10	3.56	2.67	1.28	.57	.57	16.48
Mt. Locke	5	.87	.38	.37	.22	2.70	2.78	3.45	3.00	3.42	1.25	.81	.70	19.95

TABLE 2.—Temperatures: Average Monthly and Annual Amounts in Degrees and Tenths.

Station		Record in years	January	February	March	April	May	June	July	August	September	October	November	December	Annual
Ft. Davis	Mean Max.	5	58.6	60.7	68.3	76.2	83.5	87.6	86.0	86.4	80.7	73.6	65.1	56.1	73.6
	Mean	29	43.8	48.6	55.0	62.5	70.3	74.9	75.1	73.9	68.6	61.0	51.2	45.2	60.8
	Mean min.	5	28.9	31.3	38.7	46.6	53.3	60.8	61.3	60.8	55.5	46.6	36.6	29.0	45.8
Mt. Locke	Mean max.	5	51.8	55.9	62.6	70.5	75.6	82.1	79.4	79.4	73.0	68.6	57.0	51.6	67.3
	Mean	5	42.1	45.3	51.5	58.1	64.2	70.6	69.1	69.2	63.6	58.7	47.4	42.9	56.9
	Mean min.	5	32.5	34.5	40.4	45.8	52.7	59.1	58.7	58.9	54.1	48.6	37.8	34.2	46.4

the various branches of Madera Canyon, one that will be called the middle branch having its origin at the north base of the summit. On the opposite side of the summit is the head of Pine Canyon, which occupies most of the upper part of the southern slope of the mountain. A deep gorge, the source of Goat Canyon, lies on the west slope; and the sources of Limpia and Merrill Canyons are found in the ridges about one-half mile east of the summit.

Structure of the Vegetation

Since the Davis Mountains are a part of the Rocky Mountain system, one naturally expects the vegetation to resemble that of the Cordilleras. On Mount Livermore the presence of the quaking aspen (*Populus tremuloides* Michx.) and the limber pine (*Pinus flexilis* James) indicates a tendency toward the

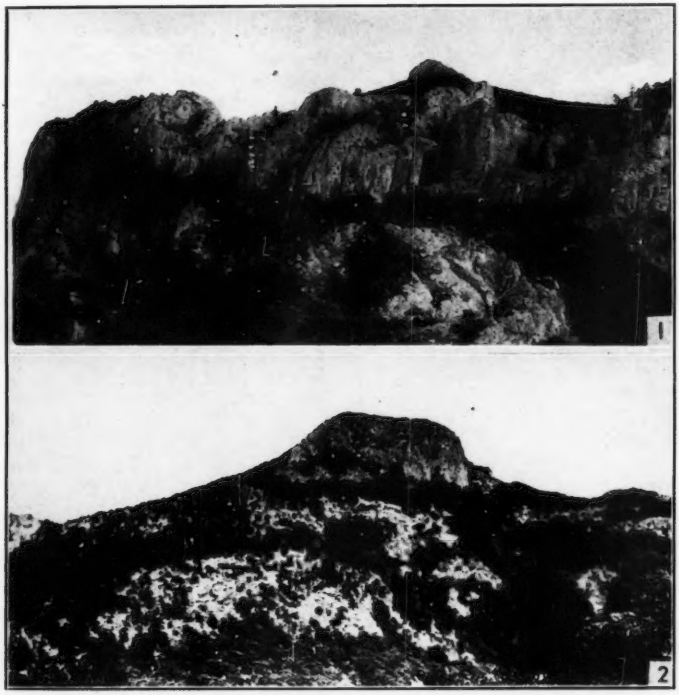

Fig. 1. Cliffs of intrusive material, the summit of Mount Livermore in background. The sources of Goat Canyon and the west branch of Madera Canyon are gorges in the right center of picture. North facing cliffs at the left.

Fig. 2. The summit of Mount Livermore showing part of the south slope. In the foreground is a little forest of gray oak in the head of Pine Canyon. Gambel's oak forms thickets at the base of the summit.

Petran subalpine forest, a formation extending along the ranges of the Rocky Mountains from Canada to southern New Mexico. The Petran montane forest, found in the Cordilleras from Canada to Mexico, is definitely represented on several peaks of the Livermore area by the western yellow pine (*Pinus ponderosa* Dougl.). Another dominant of this formation, the Douglas fir (*Pseudotsuga taxifolia* (Poir.) Rehder), present in the Chisos Mountains more than one hundred miles to the southeast, is not found in the Davis Mountains. The characteristic formation of most of the area is woodland represented by various combinations of Pinus-Quercus-Juniperus groupings.

The summit of Mount Livermore is so bare of vegetation that it was early designated as Baldy Peak and is still so named on geological survey maps. (Fig. 2). This elongated mound of rock, some forty to seventy-five feet wide and two hundred or more feet long at the base, is easily scaled on the western end; and, once at the top, one finds only scattered scrubby shrubs and a scanty growth of herbs and grasses. Though no particular plant association is represented in this restricted area, a list of the plants collected on the summit shows some variety.

Shrubs

Bouvardia ternifolia (Cav.) Schlecht.
Echinocereus chloranthus (Engelm.) Rumpler
Fendlera rupicola Gray
Holodiscus dumosus (Nutt.) Heller
Opuntia strigil Engelm.
Philadelphus argyrocalyx Wooton
Ptelea tomentosa Raf.

Forbs

Arenaria fendleri Gray
Artemisia mexicana Willd.
Brickellia brachyphylla Gray
Chenopodium incisum Poir.
Chrysopsis hispida (Hook.) Nutt.
Commelina dianthifolia Delile
Eriogonum jamesii Benth.
Galium wrightii Gray
Gnaphalium decurrens Ives
Hieracium wrightii (Grey) Robins. & Greenm.
Mirabilis comata (Small) Standl.
Phacelia congesta Hook.
Salvia arizonica Gray
Silene laciniata Cav.
Solanum fendleri Gray
Solanum nigrum L.
Thelypodium linearifolium (Gray) Wats.
Viguiera cordifolia Gray

Grasses

Agropyron arizonicum Scribn. & Smith
Bouteloua hirsuta Lag.
Bromus latiglumis (Shear) Hitchc.
Lycurus phleoides H.B.K.
Muhlenbergia glauca (Nees) Mez
Muhlenbergia polycaulis Scribn.
Stipa tenuissima Trin.

North of the summit the mountain descends abruptly by a series of broken ledges from an altitude of more than 8000 feet to less than 7500 feet. In this area, the source of the middle branch of Madera Canyon, quite characteristic vegetation is found. At the bases of the ledges and bordering the talus slopes there are thickets of Gambel's oak (*Quercus gambelii* Nutt.) and bush rockspirea (*Holodiscus dumosus* (Nutt.) Heller), while the steep slopes between the ledges usually are covered with mountain snowberry (*Symphoricarpos oreophilus* Gray). One less sloping area about one hundred yards northeast of the summit has an open grove of medium-sized western yellow pine. Near the crest of the ridge running eastward from the base of the summit is a small

grove of Gambel's oak (Fig. 3). Only a few feet over the crest on the south slope the gray oak (*Quercus grisea* Liebm.) and the alligator juniper (*Juniperus pachyphloea* Torr.) are found.

Shaded spots in the area north of the summit have a second layer of meadow rue (*Thalictrum wrightii* Gray), Arizona sage (*Salvia arizonica* Gray), and others, in various combinations of all or two or more. In the same areas, but more scattered, are found wild geranium (*Geranium atropurpureum* Heller), bedstraw (*Galium vaillantii* DC.), and giant hyssop (*Agastache verticillata* Woot. & Standl.). In less shaded spots sagebrush (*Artemisia dracunculoides* Pursh and *A. mexicana* Willd.) and gromwell (*Lithospermum multiflorum* Torr.) are prevalent. Open spots bordering the tops of the ledges are occupied by the small-jointed prickly pear (*Opuntia strigil* Engelm.), sandwort (*Arenaria fendleri* Gray), or shrubby buckwheat (*Eriogonum jamesii* Benth.); and clumps of golden aster (*Chrysopsis hispida* (Hook.) Nutt.) cling conspicuously on their walls and edges.

Below the lowermost ledge of the area and in the bed of the canyon is a peculiar plant formation consisting of quaking aspens and Gambel's oak. A large number of the aspens are small, slender specimens that resemble the straight trees of the Rocky Mountains. Mixed with the aspens are numerous specimens of the oak, almost as tall and straight as the aspens themselves. The whole plant group forms a grove of trees so thick as to hinder one's progress through it.

Just east of the aspen and oak grove a consociation of limber pine extends up a narrow tributary and a short distance down the united middle branch of Madera Canyon. Some of the trees in this small forest are seventy feet high and two feet in diameter. Fire scars occur on a few of the boles, a condition

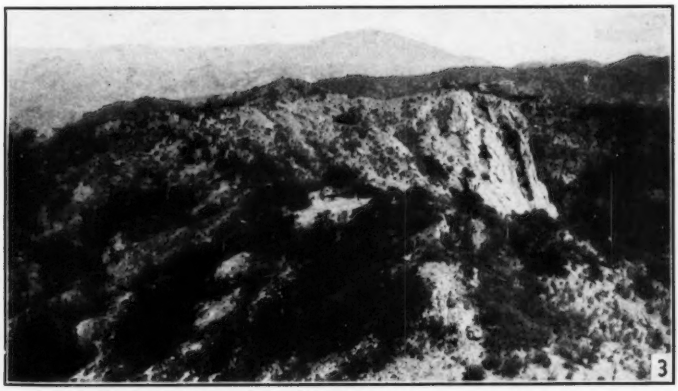

Fig. 3. Crest of ridge running eastward from base of summit of Mount Livermore. On the left is the slope leading into the middle branch of Madera Canyon and on the right is Pine Canyon. Gambel's oak on the left and gray oak on the right of the crest.

that indicates a more profuse growth of vegetation at some previous times The writer saw a fire in the Davis Mountains, probably on Mount Livermore, from a distance of thirty miles in the spring of 1928.

In the partially open spaces among the pines are thickets of bush rock-spirea and mountain snowberry. In the shaded areas there is a layer of Arizona sage and Junegrass (*Koeleria cristata* (L.) Pers.), while in the late summer and fall various species of composites are conspicuous (*Brickellia fendleri* Gray and *Eupatorium fendleri* Gray).

A list of the plants collected on the slope north of the summit down to elevation about 7400 feet is given below. This area covers the source of the middle branch of Madera Canyon.

Dominants
Pinus flexilis James
Pinus ponderosa Dougl.
Quercus gambelii Nutt.

Subdominants
Holodiscus dumosus (Nutt.) Heller
Populus tremuloides Michx.
Symphoricarpos oreophilus Gray

Other Plants
Trees
Pinus edulis Engelm.
Prunus virens (Woot. & Standl.) Standl.

Shrubs
Cercocarpus breviflorus Gray
Echinocereus chloranthus (Engelm.) Rumpler
Opuntia strigil Engelm.
Philadelphus argyrocalyx Wooton
Ptelea tomentosa Raf.
Rhamnus betulaefolia Greene
Salix lasiolepis Benth.

Lianas
Vitis arizonica Engelm.
Parthenocissus vitacea (Knerr) Hitchc.

Forbs
Achillea lanulosa Nutt.
Agastache micrantha (Gray) Woot. & Standl.
Agastache vericillata Woot. & Standl.
Allium neomexicanum Rydb.
Amaranthus powellii Wats.
Antennaria peramoena Greene
Anthericum torreyi Baker
Aquilegia chrysantha Gray
Aralia racemosa L.
Arenaria confusa Rydb.
Arenaria fendleri Gray
Artemisia dracunculoides Pursh
Artemisia mexicana Willd.
Aster oblongifolius var. *rigidulus* Gray
Astragalus yaquianus Wats.
Brickellia brachyphylla Gray
Brickellia fendleri Gray
Brickellia grandiflora (Hook.) Nutt.
Brickellia reniformis Gray
Campanula rotundifolia L.
Chenopodium fremontii Wats.
Chenopodium incisum Poir.
Chrysopsis hispida (Hook.) Nutt.
Commelina dianthifolia Delile
Cyperus fendlerianus Boeckl.
Draba gilgiana Woot. & Standl.
Dicranocarpus parviflorus Gray
Erigeron flagellaris Gray
Eriogonum jamesii Benth.
Erysimum asperrimum (Greene) Rydb.
Eupatorium fendleri Gray
Eupatorium herbaceum (Gray) Greene
Eupatorium urticaefolium Reichard
Euphorbia bifurcata Engelm.
Euphorbia chamaesula Boiss.
Galium vaillantii DC.
Gentiana bigelovii Gray
Geranium atropurpureum Heller
Heuchera rubescens Torr.
Laphamia quinqueflora Steyermark
Lappula pinetorum Greene
Lathryus graminifolius (Wats.) White
Linum lewisii Pursh
Lithospermum multiflorum Torr.
Mirabilis comata (Small) Standl.

Monarda austromontana Epling
Monarda menthaefolia Graham
Museniopsis texana (Gray) Coult. & Rose
Oxalis amplifolia (Trel.) Kunth
Pentstemon torreyi Bentl.
Phacelia congesta Hook.
Pseudocymopterus montanus (Gray) Coult. & Rose
Salvia arizonica Gray
Senecio millelobatus Rydb.
Senecio microdontus (Gray) Heller
Sicyos parviflorus Willd.
Silene laciniata Cav.
Solidago trinervata Greene
Solidago wrightii Gray
Sophia adenophora Woot. & Standl.
Stellaria cuspidata Willd.
Thalictrum wrightii Gray
Thelypodium linearifolium (Gray) Wats.
Urtica gracilis Ait.
Verbesina oreophila Woot. & Standl.

Grasses

Agropyron arizonicum Scribn. & Smith
Blepharoneuron tricholepis (Torr.) Nash
Bromus ciliatus L.
Bromus carinatus Hook. & Arn.
Bouteloua gracilis (H.B.K.) Lag.
Bouteloua hirsuta Lag.
Echinochloa crusgalli Beauv.
Festuca idahoensis Elmer
Koeleria cristata (L.) Pers.
Lycurus phleoides H.B.K.
Muhlenbergia montana (Nutt.) Hitchc.

Northwest of the area described above there is a high ridge of rock whose southern face lies just across the head of the middle branch of Madera Canyon. The north face of this ridge forms cliffs several hundred feet high, and below these cliffs the mountain slopes rapidly downward to the bed of the west branch of Madera Creek. It is on this slope, about one hundred acres in extent, that the heaviest forest is found.

At the base of the cliffs there is a triangular area of a few acres in extent consisting of talus slopes bare in spots but mostly covered with a thin accumulation of soil that supports some vegetation. Invading from below and along the edges of steeper talus slopes is Gambel's oak. Mixed with the oak and growing at still higher altitudes (about 7700 feet) is a thin grove of aspens, some of the specimens being the largest found in the Davis Mountains. While trees of this species twelve to fifteen inches in diameter would be fifty or sixty feet tall in favorable parts of the Rocky Mountains, these have struggled to reach a height of thirty-five feet.

Above the aspens there are tangles of gooseberry (*Ribes leptanthum* Gray), mountain snowberry, and bush rockspirea. Grapevines (*Vitis arizonica* Engelm.) and Virginia creeper (*Parthenocissus vitacea* (Knerr) Hitchc.) clamber thinly over the rocks, and in a crevice at the base of the cliffs is a healthy bed of malefern (*Dryopteris filix-mas* (L.) Schott). Several trees of elderberry (*Sambucus neomexicana* Wooton) are present here, the only representatives of the species in the vicinity of Mount Livrmore with the exception of two or three small trees in the upper gorge of Goat Canyon.

Below the triangular area just described is a forest typical of the north facing slopes elsewhere in the Livermore region. Numerous small tributaries of Madera Creek alternate with dry ridges and gravelly slopes. On the dry shoulders and slopes are forests of pinyon pine (*Pinus edulis* Engelm.), alligator juniper and gray oak, these species occurring in greatest abundance in the order given as one descends the slope. On the arroyo banks and the slopes that are less dry the whiteleaf oak (*Quercus hypoleucoides* A. Camus) and the western yellow pine are dominant. The whiteleaf oak usually occurs in

clumps of small trees up to four or five inches in diameter, but often it forms thickets of small shrubs hard to penetrate. The pines for the most part are young growth (Fig. 4), none of the trees having boles more than twelve inches in diameter. Dry years and infection by mistletoe (*Arceuthobium cryptopodum* Engelm.) are taking their toll, but it seems as if the stand is sufficiently thick to maintain this species as a dominant.

A list of the plants collected in the area from the base of the north-facing cliffs, elevation about 7800 feet, to a point almost a mile north where the branches of Madera Canyon unite shows quite a number of ligneous species.

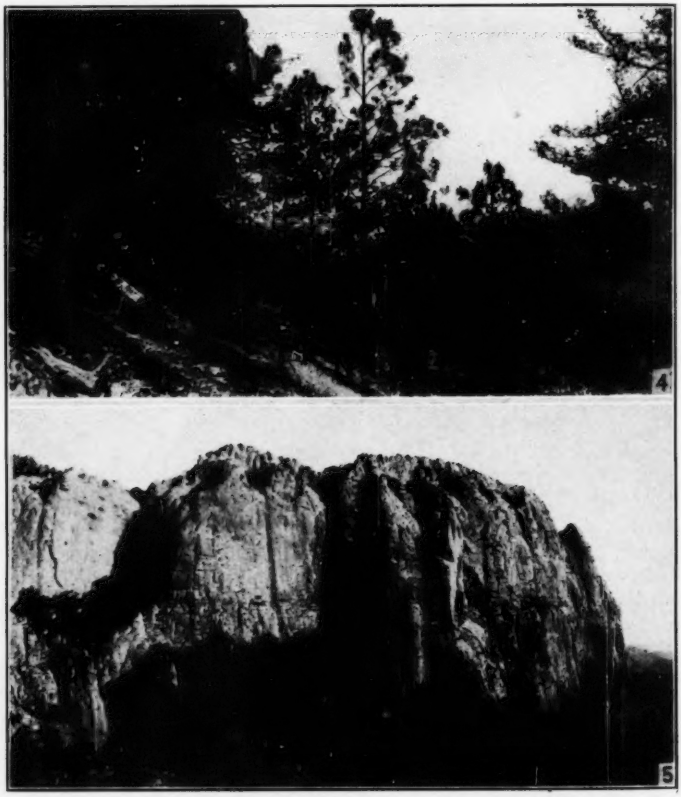

Fig. 4. Western yellow pine on the north slope of Mount Livermore. Groves like this usually are found along the arroyo banks and on somewhat dry rocky slopes.

Fig. 5. West facing cliffs of Mount Livermore. Aspens and western yellow pines form the forest here.

Dominants

Juniperus pachyphloea Torr.
Pinus edulis Engelm.
Pinus ponderosa Dougl.
Quercus grisea Liebm.
Quercus hypoleucoides A. Camus

Subdominants

Pinus flexilis James
Populus tremuloides Michx.
Querculs gambelii Nutt.

Other Plants

Trees

Arbutus texana Buckl.
Quercus gravesii Sudw.
Sambucus neomexicana Wooton

Shrubs

Cercocarpus breviflorus Gray
Holodiscus dumosus (Nutt.) Heller
Ptelea tomentosa Raf.
Ribes leptanthum Gray
Symphoricarpos oreophilus Gray

Lianas

Parthenocissus vitacea (Knerr) Hitchc.
Vitis arizonica Engelm.

Forbs

Allium neomexicanum Rydb.
Brickellia grandiflora (Hook.) Nutt.
Brickellia hinckleyi Standl. sp. nov.
Campanula rotundifolia L.
Chenopodium incisum Poir.
Erysimum asperrimum (Greene) Rydb.
Galium vaillantii DC.
Galium wrightii Gray
Geranium atropurpureum Heller
Lithospermum multiflorum Torr.
Pseudocymopterus montanus (Gray) Coult. & Rose
Salvia arizonica Gray
Senecio millelobatus Rydb.
Silene laciniata Cav.

Grasses

Bouteloua hirsuta Lag.
Muhlenbergia emersleyi Vasey
Piptochaetium fimbriatum (H.B.K.) Hitchc.
Setaria grisebachii Fourn.

The slope leading southward from the base of the summit has an oak-pinyon association. A very fine grove of gray oak, about two acres in extent, is growing near the western end of the slope in the upper limits of Pine Canyon (Fig. 2). A few low, spreading specimens of the pine are found ranging eastward from the oak grove where the mountain slopes abruptly from more than 8000 feet elevation to about 7500 feet into the canyon. Scraggly specimens of the alligator juniper are scattered over the upper part of the slope, and on its dry shoulders there occur thickets of mountain mahogany (*Cercocarpus breviflorus* Gray). Unshaded areas have a fairly good covering of hairy grama (*Bouteloua hirsuta* Lag.) or wolftail (*Lycurus phleoides* H.B.K.), while otherwise bare spots sustain clumps of the prostrate prickly pear or shrubby wild buckwheat. Noticeable under the more scattered trees, protected by their shade, are the foxtail (*Setaria grisebachii* Fourn.) and the goosefoot (*Chenopodium incisum* Poir.). Other plants most commonly found in the shade are the four-o'clock (*Mirabilis wrightiana* Gray), the nettle (*Urtica gracilis* Ait.), and sagebrush (*Artemisia mexicana* Willd.).

A list of the plants collected on the southern slopes of Mount Livermore

shows some contrast to the vegetation of the north slope. The dominants of the upper northern slope are not present in any great number on the exposed southern slope, and the dominants of the upper southern slope are found at five hundred feet or more lower elevation on the northern slope. Except in the case of the grove of gray oak, the trees on the south slope are rather scattered; but the forests on the north slope are often quite thick.

Dominants

Pinus edulis Engelm. — *Quercus grisea* Liebm.

Subdominants

Bouteloua hirsuta Lag. — *Cercocarpus breviflorus* Gray

Other Plants

Trees

Juniperus pachyphloea Torr. — *Quercus gambelii* Nutt.
Prunus virens (Woot. & Standl.) Standl.

Shrubs

Adolphia infesta Meisn. — *Holodiscus dumosus* (Nutt.) Heller
Bouvardia ternifolia (Cav.) Schlecht. — *Opuntia strigil* Engelm.
Echinocereus chloranthus (Engelm.) Rumpler — *Ptelea tomentosa* Raf.
Fendlera rupicola Gray — *Rhamnus betulaefolia* Greene
Symphoricarpos oreophilus Gray

Forbs

Acalypha neomexicana Muell. Arg. — *Ipomoea lindheimeri* Gray
Agastache micrantha (Gray) Woot. & Standl. — *Lathyrus graminifolius* (Wats.) White
Amaranthus powellii Wats. — *Linum lewisii* Pursh
Arenaria fendleri Gray — *Lotus rigidus* (Benth.) Greene
Artemisia mexicana Willd. — *Mentzelia aspera* L.
Astragalus yaquianus Wats. — *Mirabilis aggregata* (Ort.) Cav.
Bahia bigelovii Gray — *Mirabilis wrightiana* Gray
Brickellia brachyphylla Gray — *Monarda austromontana* Epling
Castelleja sessiliflora Pursh — *Oxalis amplifolia* (Trel.) Kunth
Chenopodium fremontii Wats. — *Paronychia jamesii* Torr. & Gray
Chenopodium incisum Poir. — *Parosela filiformis* (Gray) Heller
Chrysopsis hispida (Hook.) Nutt. — *Portulaca lanceolata* Engelm.
Commelina dianthifolia Delile — *Relbunium microphyllum* (Gray) Hemsl.
Conyza sophiaefolia H.B.K. — *Salvia arizonica* Gray
Cosmos parviflorus H.B.K. — *Sedum wrightii* Gray
Cyclanthera dissecta (Torr. & Gray) Arn. — *Senecio millelobatus* Rydb.
Cyperus fendlerianus Boeckl. — *Sicyos parviflorus* Willd.
Drymaria fendleri Wats. — *Sisymbrium wrightii* Gray
Eriogonum jamesii Benth. — *Solanum fendleri* Gray
Erysimum asperrimum (Greene) Rydb. — *Solanum nigrum* L.
Euphorbia bifurcata Engelm. — *Sophia adenophora* Woot. & Standl.
Froelichia gracilis (Hook.) Moq. — *Talinum chisosense* Mueller
Galinsoga semicalva (Gray) St. John & White — *Talinum parviflorum* Nutt.
Galium vaillantii DC. — *Thalictrum wrightii* Gray
Galium wrightii Gray — *Thelypodium linearifolium* (Gray) Wats.
Geranium atropurpureum Heller — *Thelypodium micranthum* (Gray) Small
Geranium mexicanum H.B.K. — *Urtica gracilis* Ait.
Gnaphalium decurrens Ives — *Verbena neomexicana* (Gray) Small
Hedeoma plicata Torr. — *Verbesina oreophila* Woot. & Standl.
Ipomoea cardiophylla Gray — *Viguiera cordifolia* Gray
Viguiera multiflora (Nutt.) Blake
Yucca baccata Torr.

Grasses

Aristida divaricata Humb. & Bonpl.
Blepharoneuron tricholepis (Torr.) Nash
Bouteloua gracilis (H.B.K.) Lag.
Bouteloua hirsuta Lag.
Bromus anomalus var. *lanatipes* (Shear) Hitchc.
Bromus latiglumis (Shear) Hitchc.
Bromus marginatus Nees
Festuca idahoensis Elmer
Koeleria cristata (L.) Pers.
Lycurus phleoides H.B.K.
Muhlenbergia depauperata Scribn.
Muhlenbergia glauca (Nees) Mez
Muhlenbergia montana (Nutt.) Hitchc.
Muhlenbergia polycaulis Scribn.
Setaria grisebachii Fourn.

Below 7500 feet elevation Pine Canyon drops abruptly for several hundred feet. Here where the canyon is narrow the most noticeable trees are wild cherries (*Prunus virens* (Woot. & Standl.) Standl.). At 7000 feet and for some distance downward clumps of the whiteleaf oak are found. Thin groves of western yellow pine in the upper half of its course give Pine Canyon its name; but the writer, first entering at its junction with Merrill Canyon three miles south of Mount Livermore, called it "Redoak" Canyon from the numerous trees of Graves' oak (*Quercus gravesii* Sudw.) found in its lower reaches. As Pine Canyon widens to merge with Merrill Canyon, Emory's oak (*Quercus emoryi* Torr.) forms an open forest, which extends both up and down Merrill Canyon from the mouth of the tributary.

Merrill Canyon has its origin in the ridges east of the summit. The ridge extending east from the base of the summit is split into several divisions, and it is about one mile east of the top of the mountain in some of these ridges that this canyon starts in an easterly direction. Forming a gradual curve, it has changed to a southwesterly direction by the time it has united with Pine Canyon.

On the slopes leading down into the source of Merrill Canyon there are numerous alligator junipers, but as the canyon begins to drop abruptly these are replaced by whiteleaf oak. At an altitude of about 6600 feet and continuing down the canyon for more than a mile the reticulate-leaf oak (*Quercus reticulata* Humb. & Bonpl.) forms a forest covering the canyon bed. This is the only canyon in the vicinity of Mount Livermore that has this oak. Below an elevation of about 6200 feet Emory's oak becomes the dominant tree of the canyon.

The upper sources of Limpia Canyon have their origin on the northern slopes of the ridges east of the summit. The two divisions of upper Limpia have vegetation tending toward the Petran subalpine forest, for here are found both the aspen and the limber pine. It was somewhere in this canyon that a government sawmill was built to furnish lumber for old Fort Davis, and at some future date more lumber can be procured from the present stand of western yellow pine and the limber pine found there.

This forest is replaced at an elevation of about 7300 feet by forests and thickets of the whiteleaf oak with frequent specimens of western yellow pine mixed with the oak. Since the general direction of the canyon is eastward for

some two miles, the Pinus- Quercus association consisting of whiteleaf oak and western yellow pine has a greater extent in length here than in any other canyon. At an elevation of about 6100 feet the canyon widens; and Emory's oak is found mixed with the whiteleaf oak, which it finally replaces a little farther downward. It was in this area where whiteleaf oak, Emory's oak, and western yellow pine are in close proximity that the writer helped procure large blocks of the trunks of these trees for exhibiting at the Texas Centennial several years ago. The blocks, almost two feet in diameter, were not the largest that might be found in the area.

Just west of the summit of Mount Livermore a short gentle slope is ended by a series of jagged peaks and precipices cut by a half dozen gorges (Fig. 1). One of these gorges is the source of Goat Canyon; another is the main source of the west branch of Madera Canyon. These two gorges, because of their proximity and similar exposure, have similar vegetation. A few of the typical plants common to both gorges are listed here.

Trees

Pinus ponderosa Dougl.
Prunus virens (Woot. & Standl.) Standl.
Quercus gambelii Nutt.

Shrubs

Holodiscus dumosus (Nutt.) Heller
Rhamnus betulaefolia Greene

Lianas

Parthenocissus vitacea (Knerr) Hitchc.
Vitis arizonica Engelm.

Forbs

Aquilegia chrysantha Gray
Artemisia mexicana Willd.
Chrysopsis hispida (Hook.) Nutt.
Erysimum asperrimum (Greene) Rydb.
Euphorbia bifurcata Engelm.
Geranium atropurpureum Heller
Heuchera rubescens Torr.
Polemonium hinckleyi Standl. sp. nov.
Silene laciniata Cav.
Solanum fendleri Gray
Thalictrum wrightii Gray
Urtica gracilis Ait.
Verbesina oreophila Woot. & Standl.

At the base of the cliffs from which Goat Canyon gorge emerges the vegetation is almost identical with that below the north-facing cliffs previously described, the conditions of soil, light, temperature, and moisture being quite similar in the two localities. Western yellow pine, Gambel's oak, and aspens form a small forest.

Below this forest at about 7500 feet the canyon is characterized by a thick forest of whiteleaf oak, which about one mile downward merges with Emory's oak. The latter then comprises the entire forest, except for scattered specimens of Grave's oak, for some four miles down the canyon to its junction with Merrill Canyon.

High up in the cliffs forming the southwest face of Mount Livermore (Fig. 5) there is an amphitheater-like pocket. Because it is partially protected from wind and sun, the vegetation in this pocket is less subjected to drying than the south slope in general. An accumulation of humus and only a narrow

gap for water runoff have built up a deeper soil which maintains a high moisture content. Some variety in the list of trees and shrubs may be noted, some of the largest trees in the Davis Mountains being located here.

Trees

Juniperus pachyphloea Torr.
Pinus edulis Engelm.
Pinus flexilis James
Pinus ponderosa Dougl.
Prunus virens (Woot. & Standl.) Standl.
Quercus gambelii Nutt.
Quercus grisea Liebm.

Shrubs

Cercocarpus breviflorus Gray
Ptelea tomentosa Raf.
Symphoricarpos oreophilus Gray
Yucca baccata Torr.

The ridges radiating from the vicinity of Mount Livermore have for the most part a thin cover of woodland climax consisting of pinyon pine, alligator juniper, and gray oak, these species occurring in the order of their ability to withstand xerophytic conditions as one progresses away from the mountain. Some of the south-facing ridges are bare of forests in quite large spots, sacahuiste (*Nolina texana* Wats.) and the Spanish dagger (*Yucca baccata* Torr.) being dominant in such areas. The leafless buckthorn (*Adolphia infesta* Meisn.) is prevalent on many of the south and west facing slopes and shoulders of some of these bare ridges.

West of Mount Livermore and separated from it by a pass about one-fourth mile wide is a high ridge extending in a general east-west direction. The vegetation on this ridge is quite like that of the north and south slopes of the peak itself. At the foot of the north slope of this ridge, however, is H O Canyon, whose source is not on the mountain but on a pass separating the canyon from the west branch of Madera Canyon. The north slope of this western ridge furnishes most of the drainage into the upper reaches of H O Canyon, several tributaries from the ridge uniting with the canyon within the two miles of its western extent to the foot of Sawtooth Mountain. In a well watered spot in the bed of H O Canyon about a mile down from its origin there are several large walnut trees (*Juglans major* (Torr.) Heller). Some of the specimens are more than a foot in diameter and almost fifty feet high.

Summary

The Davis Mountains are a lava region resulting from deformational movements of late Cretaceous time, later lava flows, and consequent severe erosion. Mount Livermore, the highest point in the group, probably marks the line of a fissure eruption.

Early botanical work on the area was done by collectors and descriptive writers; investigations since 1900 have dealt mostly with the ecological phases of botany.

Comparison of the records of Fort Davis and McDonald Observatory on Mount Locke indicates an average annual precipitation of at least twenty-five inches on Mount Livermore.

The vegetation of the north slope of Mount Livermore is a part of the Petran montane forest. Most of the area belongs to the oak woodland or to various combinations of Pinus-Juniperus-Quercus groupings. Some of the canyons have their own characteristic vegetation.

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Book Reviews

MAN'S UNKNOWN ANCESTORS. By Raymond W. Murray. Milwaukee, Bruce Publishing Co., 1943. xiv + 384 pp., 36 plates. $4.25.

Archeologic discoveries of the past dozen years have been so numerous and important as to render obsolete the works of Osborn, Sollas, Obermaier and others. As a result, there has been grave need for some new general and readable work for students and that part of the public which wishes to be informed.

To a great extent this need is met by Professor Murray's volume. For it is a comprehensive survey of prehistoric archeology; a work which frankly presents the researches of others, with a balance which the specialist in any one field might not readily achieve. Especially valuable is its thorough treatment of New World cultures and skeletal remains, since these have been neglected or minimized in several other works. Professor Murray makes no claims for extreme antiquity, but he does show that American finds have been significant, and that they may in time fill a large niche in the prehistory of man.

Man's Unknown Ancestors opens with a survey of archeologic progress and techniques, followed by a chapter which summarizes geologic history. In this there are a few minor errors, such as the statement that sea plants appeared in the Paleozoic, that trilobites were king crabs, and that Carboniferous climates were hot. Geologists also will question tables (end papers and page 32) which raise the Tertiary to the rank of era and do the same for the Quaternary. Such matters, however, are details which do not seriously reduce the value of this condensed summary.

Part II, containing three chapters, deals with human and sub-human races of the prehistoric Old World. Professor Murray tentatively uses the Weidenreich classification, which places all these races in the genus *Homo* and recognizes only three species: *H. erectus*, *H. neanderthalensis*, and *H. sapiens*. The first of these includes Pithecanthropus and Peking men as subspecies; the second has three major divisions typified by Rhodesian, Spy and Ehringsdorf remains, and the third includes types that range from Piltdown to modern races. Professor Murray accepts the Swanscombe find as one which carries the history of *H. sapiens* back at least to the second interglacial epoch and strengthens the argument of those who find a long-established gap between *sapiens* and *neanderthalensis* branches of the human family tree.

Part III reviews Old World cultures, with attention to reasonable inferences upon psychology, social structure and religious beliefs. Here the mass of data is so great that readers who are seriously interested must go to older works.

Part IV is the most novel of all, since it deals with prehistoric man in the Americas. Professor Murray shows how early rash assumptions by Ameghino and others led to the extreme conservatism of Hrdlicka, who seemed to deny significance to American finds just because they were American. A new period began about 1930, after Brown and Figgins established the significance of Folsom points in association with extinct mammals. This was followed by a long series of discoveries in the Southwest, revealing cultures whose ages seem to range from 8,500 to 20,000 years. Still older are the Abilene and Sandia (New Mexico) finds, as well as the Black's Fork and Durst Eolith cultures. Variously assigned to the Wisconsin (fourth glacial) and Sangamon (third interglacial) epochs, these artifacts may have ages ranging from 30,000 to more than 70,000 years. Yet some authors find them less convincing than the heavy-jawed, primitive-toothed Minnesota girl, which both Bryan and MacClintock assign to the early postglacial epoch. An excellent photograph of the Minnesota skull appears on page 254.

Professor Murray follows his discussion of early American antiquities with chapters on the late prehistoric of the Southwest, on "Mound, Totem Pole, and Igloo Builders,"

on Indian civilizations, and on red men of "yesterday." His book closes with a chapter on prehistory in relation to religion, a reading list, and a glossary. Many readers will find the first of these a useful and perhaps surprising statement of the Catholic attitude toward prehistory and evolution. For, though Professor Murray is right in saying that "American Catholics need to be reminded that the Catholic view is not that of the Fundamentalists," the need is not so limited.

A specially useful feature of the book is end papers which give the geologic distribution of cultures and fossil men, based on the assumption that the Pleistocene lasted about one million years. However much a few archeologists may complain, no geologist will find the dates given to exceed probability.—CARROLL LANE FENTON.

MITOSIS: THE MOVEMENTS OF CHROMOSOMES IN CELL DIVISION. By Franz Schrader. Columbia University Press, New York, 1944. x + 110 pp., 15 figures. $2.00.

Every biologist has some conception of mitosis. Though he knows that the subject is in a doubtful state, he nearly always chooses some one of the many explanations of the process which he then uses in his thinking and teaching. Naturally his choice of hypothesis is influenced by his own observations or at any rate by those of his co-workers in his own special field. Witness the unanimity with which the geneticists of the last ten years have accepted an electrostatic hypothesis, and the equally concerted resistance with which cellular physiologists have met such an interpretation. Certainly it is very difficult to evaluate the myriad opinions and findings regarding mitosis in a wholly fair and detached way. Only a cytologist like Schrader could possibly have done so. The resulting monograph proves to be a very readable and informative account of the phenomena associated with and underlying chromosome movements, as well as a most stimulating analysis and critique of the sundry hypotheses extant today.

Apart from the brief introduction, a short chapter on problems related to mitosis and the concluding remarks, the body of the book is nearly equally divided between an explanation and generalization of the facts now forming the core of our knowledge about the mitotic machinery, and a skillful probing of current hypotheses in the light of these facts. Most biologists will be amazed at the number of discrete, formal explanations—of various degrees of ingenuity—which have been advanced in the last fifty years. They range from simple mechanical hypotheses involving mere pulling or pushing by spindle fibers through electrostatic explanations, complicated hydrodynamic systems (as the Bjerknis phenomenon) and tactoids, to a direct affirmation of chromosomal autonomy. Schrader classifies these interpretations into ten categories, each of which groups sufficiently related schemes to allow of comparative analysis. The results of his critical evaluation are in most cases devastating, and this chapter is certainly the Valhalla of most speculations about mitosis. Prominent views which fail as satisfactory working hypothesis are those of Darlington and Rashevsky. Darlington has so intricately elaborated Lillie's older (and more acceptable) electrostatic hypothesis that, apart from a lack of supporting data, it becomes no more than a redescription of the events themselves. It is incapable of generalization without particularization, or of prediction without foresight. The diffusion-force hypothesis is bereft of support, for Bělar's data are shown to fit the theoretical curve because Rashevsky erred in their interpretation.

It should not be construed that the analysis is solely destructive, however. True, none of the many hypotheses which have been formulated is found in even reasonable agreement with the data as a whole. But Schrader is not unaware of such virtues as each may possess, and he is quick to point out the favorable and heuristic elements involved. He convincingly argues, and asks, that cytologists and all who concern themselves with mitosis set more limited goals, that enlightened attacks on single phases of the mitotic cycle be made. "The attitude of the past that the answer will some day be revealed to us by a stroke of genius or by luck is almost certainly illusory. The solution will be approached much more surely if we make up our minds that we are confronted by some painstaking work that has to be guided by intelligent planning and a thorough knowledge of the results so far obtained."

In "Related Problems' (chapter 3) the status of current views and research on the energic nucleus, synapsis, polarization, nuclear membrane, telomere, etc., is briefly sketched. This survey is perhaps too brief, but it serves the point of drawing attention to a miscellany of apparent "forces" and phenomena which may well be operative in various parts of the mitotic cycle and which are sorely in need of more exacting analysis and elucidation by the cytologist.

To those who wish to read further in the literature of mitosis the bibliography will prove a thoroughly satisfactory and up-to-date guide. Although, for purposes of convenience, it is arbitrarily restricted to articles most of which have appeared within the past twenty years, the list of citations runs to more than four hundred references. The text is most exemplarily documented, and rarely is one at variance with Schrader's appraisal of the literature. Yet it seems to the reviewer that few will accept Jollos and Péterfi's "demonstration" of cytoplasmic cleavage in the absence of nuclear material (pp. 2, 29); the figures clearly portray amphibian eggs in progressive cytolysis. Again, a less casual reference to Carlson's findings (p. 24) regarding the movement of akinetic chromosome fragments would appear required in a critique such as this monograph. It is very probable that the akinetic fragments which attained the poles did so through the mediation of those extra-spindle forces which are responsible for a roughly quantitative distribution of golgi and chondriosomal elements in mitosis. Nor does mere identity of refractive indices account for the apparent absence of astral rays in most plants (p. 30); astral rays are also absent in fixed and stained plant cells and, by our present standards, hence probably non-existant in these cells.

But adverse criticisms are few indeed. Professor Schrader has given biologists a book for which they have long felt a need and which should prove a stimulus to new work on mitosis. It is not a book for the cytologist or geneticist alone. The physiologist, biophysicist, embryologist, pathologist and all teachers of cellular biology will find here an enjoyable and ready means for coming abreast of today's information and ideas about that fundamental puzzle—mitosis.—KENNETH W. COOPER.

THE FLOWERING PLANTS AND FERNS OF MOUNT DIABLO, CALIFORNIA: THEIR DISTRIBUTION AND ASSOCIATION INTO PLANT COMMUNITIES. By Mary L. Bowerman. The Gillick Press, Berkeley, California. 1944. xi-290 pp. 26 figs. $3.75.

Mount Diablo, one of the central landmarks in the state of California, has been a favorite collecting area of botanists since 1861. Now, for this area, Dr. Bowerman presents one of the most concise and complete ecological aand taxonomic treatments that is available in this country.

The contents of the book are divided into the following sections. Part I consists of a brief diiscussion of the physical factors of the area including position, topography, climate, soils, geology and paleobotany. Part II is an ecological treatment of Mount Diablo beginning with an enumeration of the life zones (which follows the Merriam concept, an unfortunate circumstance since this concept is not only based on errors but is also untenable for wide areas); the plant communities are delimited and the characteristic species of these listed; and the succession of the woodland, grassland, and chaparral climaxes given. Part III briefly correlates the vegetation, soils, and geological features of the area. Part IV is a statistical treatment of the distributional patterns of the vegetation. Approximately 70% of the species inhabit the base of the mountain. The number of species decreases with altitude, and only 9% are restricted to the upper slopes. There are 6 endemics in the region, also a small remnant of a Pliocene flora which was Mexican in origin, a few northern species which reach their southern limit of distribution here, and a few southern species which are at the northern limit of their range. Many of the grasses are common to the Great Valley. Most of the species of Mount Diablo are typical of the Coast Ranges. Ninety-one of the seed plants are introduced species, mainly from the Mediterranean region. Part V is comprised of a list of the Botanical collections of the area including the type specimens which have been described from

this region. Part VI is an annotated catalog of the vascular plants including keys to the families, genera and species. One of the most useful features of the book is the information which is presented with each species. This includes the common name, synonyms, habitat, exposure, elevation, relative abundance, time of flowering or fruiting, the plants with which each species is associated and the localities where collections have been made. In many instances, particularly with the dominant plants, this information consists of several paragraphs which will be particularly useful to many ecologists. Part VII concludes the book with a list of the literature cited, a glossary of the terms used, and an index.

The wide range of useful information and clear illustrations make this book valuable to botanists in all parts of the country as well as to the local botanists.—D. PARKER.

THE BIOTIC PROVINCES OF NORTH AMERICA. By Lee R. Dice. University of Michigan Press, Ann Arbor, Michigan, 1943. viii + 78 pp., 1 Map. $1.75.

Plant ecologists and plant geographers particularly will regret the appearance of this book because its contents, if adopted by uncritical investigators, will obscure the endeavors of a few workers who have been trying to define and delimit the natural units of vegetation on this continent.

The statement is made that "actually, the classification of biotic provinces here presented is based to a very large extent on the vegetation.... The vegetation accordingly offers for the present the most satisfactory basis for distinguishing the major ecologic communities of the continent." This statement leads the reader to expect a classification of biotic provinces based on the distribution of the major plant communities, but this does not happen. Instead, some of the major plant communities are treated in such a way that they are included in several biotic provinces or in some instances several distinct plant communities are included within the same biotic province. For example, the alpine vegetation of western United States is placed in 6 distinct biotic provinces, the subalpine, montane and woodland climax communities likewise occur in several different provinces while within the single province, the Californian biotic province, is placed desert, grassland, chaparral, sclerophyllous woodland, montane forest, subalpine forest and alpine vegetation. Certainly the distinction between these diverse types is as marked (or more so) than the distinctions between the provinces in the middle west or eastern United States.

The definitions used in this text do not have sharply contrasted criteria. Continuity of the geographic area of the communities is considered as a fundamental characteristic of the described biotic units. The rigid application of this criterion leads to the unnatural separation into several biotic units of major plant communities (such as the alpine vegetation, or sagebrush areas in western United States as mentioned above) and places them with other communities which are not only dissimilar in origin, history and composition, but also occupy areas having a different climate, different soils, and different physiographic features.

Twenty-nine biotic provinces are delimited. Although the book is entitled the biotic provinces of North America, southern Mexico and all of Central America are omitted because, according to the author, too little ecological information of these areas is available. No reference is made to the numerous plant ecological, plant geographic and taxonomic studies which have been made in these areas by many investigators. In spite of the author's statement that vegetation is the basis for delimitation of the provinces, only one is named for the dominating vegetation of the area—the Artemisian biotic province. All of the others are geographic names (or Indian names which bear a geographic connotation).

Concise definitions and an adherence to the principles of plant geography (if vegetation is the basis for the recognition of biotic units) would surely improve this classification.—D. PARKER.

SOYBEAN CHEMISTRY AND TECHNOLOGY. By Klare S. Markley and Warren H. Goss. Chemical Publishing Co., Inc. Brooklyn 2, N. Y., 1944. iii + 261 pp. $3.50.

To write a technical book about an agricultural product, such as the soybean, which has reached an annual production of approximately 200 million bushels, requires courage plus scientific background and infinite patience. To have packed the essentials from the chemical literature and from the industrial development of the industry into 261 pages is a masterpiece of abstracting.

The book is divided into two parts. Part I deals with the chemical composition of the soybean and the chemistry of constituents isolated from it. Highlights of this part include protein and other nitrogen constituents, carbohydrates, glycosides, vitamins, oil and oil-soluble constituents, physical and chemical characteristics of soybean oils, fatty acids and glycerides, sterols, oil-soluble pigments, antioxidants and phosphatides, with a list of 477 references at the end.

The first part is in the style of a review of the literature peppered with critical comments and pertinent contributions from the authors' own work. The reviewer wishes that the authors had more often expressed their views as to the reliability of the information gleaned from the literature, particularly from Oriental papers. Much of the Oriental work on glycosides, for example, needs confirmation.

From the point of view of the chemist, the historical part of the introduction and also the definitions and general discussions under each of the vitamins could have been omitted, thereby leaving several pages for wider discussion of soybean chemistry. However, these are well presented and may be helpful to many.

The book is almost free of errors (only one typographical error was noted—on page 56, line 1, where the t was omitted from the word heating). On page 31, line 10, obviously adsorbent was intended, and on line 11 likewise, adsorption instead of absorption.

To the research worker Part I is a veritable Beilstein of information on soybean chemistry, and to students and others desiring a slice of the best meat of soybean research this book is the answer.

Part II deals with "Processing of Soybeans and Soybean Products." The history of the development of soybean processing up to 1943 is outlined, with 207 references cited and listed at the end. It is well illustrated with photographs and drawings. A table of manufacturers of processing equipment and one of soybean processing mills in the United States are presented. A subject index covering both parts is included.

Anyone interested in soybeans or in research on the chemistry and utilization of any agricultural product should have this book.—E. D. WALTER, Bureau of Agricultural and Industrial Chemistry, Salinas, Calif.

MUSHROOMS OF THE GREAT LAKES REGION. By Verne Ovid Graham. Chicago Academy of Sciences and Chicago Natural History Museum, 1944. vii + 390 pp., 49 plates. $4.50.

This attractive volume, sponsored jointly by the two institutions whose names appear on the title page, should do much to further interest in the study of the larger fungi of the north central United States. The title is somewhat misleading, but the subtitle: "The fleshy, leathery and woody fungi of Illinois, Indiana, Ohio and the southern half of Wisconsin and of Michigan," states accurately the scope and range. It will, of course, be extremely useful far beyond the stated geographical limits. The plates are reproduced in collotype and each plate includes a number of drawings, comprising in all 866 figures, so that the great majority of the genera and about two-thirds of the 1200 species described are illustrated. Most of the drawings are excellent and in many cases the artists have been singularly successful in bringing out in black and white the elusive but characteristic appearances of the species illustrated.

There is a single key to all genera and keys are given to the species of all genera where more than one or two species are recognized as occurring within the area covered. The taxonomic treatment is extremely conservative. Within limits, conservatism in this respect may well be an advantage in a book intended for popular use, but some conces-

sion to modern views would have improved the volume without impairing its usefulness. So far as the larger Ascomycetes, the polypores, the agarics and gasteromycetes are concerned—and these are the groups for which the book will be mostly consulted—the work will be eminently serviceable. The treatment of the resupinate genera and of the tremellaceous forms is less satisfactory. Thirteen species of *Corticium* are listed, constituting only a small proportion of those occurring in the area, and these are keyed on the basis of external characters only, spore dimensions being given for but a single species. Obviously, any attempt to determine a member of this difficult genus from such a key can lead only to confusion. The same treatments apply to the treatments of *Peniophora*, *Hymenochaete* and *Stereum*. Numerous errors and omissions might be cited among the tremellaceous fungi and the inclusion of *Sebacina* and *Tremellodendron* in the Thelephoraceae is scarcely defensible at the present time.

There is no general bibliography, but references are cited under most of the family headings. So far as the Polyporaceae, Agaricaceae and gasteromycete groups are concerned, the citations are adequate, but much of the significant literature relating to the so-called lower Basidiomycetes is ignored. The ground to be covered is so extensive that these defects may be pardoned in a book which comes nearer than any previously published in the United States to constituting a comprehensive and usable popular manual of the larger fungi of an extensive region.—G. W. MARTIN.

THE OSTEOLOGY AND MYOLOGY OF THE CALIFORNIA RIVER OTTER. By Edna M. Fisher. Stanford University Press, Stanford University, Calif. 1942. 72 pp., 37 figs. $1.50.

Not so long ago descriptive and comparative morphologists were looked upon as deplorable vestiges of a gloriously overcome, dull period of biological endeavor. More recently however, even some of the most confirmed experimentalists have come to realize that morphological knowledge forms not only the basis upon which all experimental work must rest, but that time and again morphological research has suggested to the experimental biologist the very problems whose solution appeared particularly promising by experimental investigation. Thus morphological interest is being revived.

Unfortunately, some recent anatomical contributions lack the very essence of morphology, namely the basic recognition that the study of form takes on meaning only in the light of form relationships (morphological relationships). Unrelated, descriptive anatomy has a *raison d'être* only in medicine, where it can pursue purely practical purposes.

The present account of the osteology and myology of the California river otter represents an example of totally uncorrelated anatomical work. The reader learns from the "Preface" that this first contribution contains the results of a preliminary investigation which should lay the basis for further comparisons with the morphology of the sea otter and finally with remains of Indian shell mounds. So far, so good. But upon reading this publication one can hardly overcome the impression that a compendium of cat anatomy is at hand. The reader is confronted with an anatomical *fait accomplit* or merely with the results of undoubtedly extensive work, but is not told how the author arrived at her conclusions. If "the grosser aspects of the anatomy of this form follow the general carnivore type and are quite similar in many ways to the anatomy of the cat," as the author points out, then it would be doubly important to know in what respects the two forms are similar or dissimilar. Thus the author kept to herself the knowledge of how the anatomy of the California river otter compares wiith other anatomically well known carnivores. It might also be interesting to know what literature the author consulted in the preparation of this account. The report ends as abruptly as it begins. There is neither an introduction which might familiarize the reader (who most likely has only a superficial acquaintance with carnivore anatomy) with the more general aspects of the morphology of the group, nor a statement at the end which might indicate some of the more important results obtained.

It is hoped that the author will correct these shortcomings in her future contributions, since the problem is well worthy of detailed consideration and promises to add further insight into the interesting question of secondary acquatic adaptation.—RAINER ZANGERL.